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A Study of Selected Problems in Armor Operations

by

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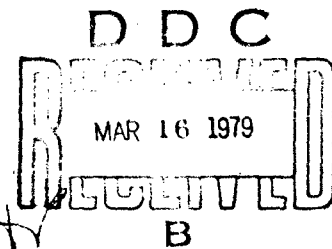
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Information on the kind and extent of training in escape or evacuation of injured personnel was obtained by a questionnaire from 33 crewmen with actual experience in escape and evacuation. Results showed that current training is extremely limited. If a tank is hit, the gunner is the most vulnerable crew member. Lifting straps built into a tanker's uniform would aid considerably in the evacuation of wounded or injured personnel.

Target acquisition performance of tank commanders operating in the closed-hatch mode under different conditions was compared to performance in the normal open-hatch mode. Results showed that target acquisition performance is not affected significantly by slew rate, cupola position, or the use of an aiming reference, and is not degraded in the closed-hatch mode.

A literature survey on deriving Measures of Effectiveness (MOE) for tank crews revealed that techniques for deriving MOE for crews or larger personnel units are not well developed. Current work on MOE for tank crews primarily concerns gunnery performance.

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FOREWORD

The Fort Hood Field Unit of the Army Research Institute for the Behavioral and Social Sciences (ARI) provides support to Headquarters, TCATA (TRADOC Combined Arms Test Activity; formerly called MASSTER--Modern Army Selected Systems Test Evaluation and Review). This support is provided by assessing human performance aspects in field evaluations of man/weapons systems.

This report presents the results of four separate efforts in the area of armor operations. One of the efforts was designed to determine the effects of external environmental conditions on the internal environment of a buttoned-up tank. Another effort was a study of problems in escape and evacuation from armored vehicles. A third effort was an experimental investigation of target acquisition in the closed-hatch mode, with emphasis on the use of an aiming reference to prevent spatial disorientation. The fourth effort was concerned with the problems involved in the development of Measures of Effectiveness (MOE) for tank crews.

ARI research in this area is conducted as an in-house effort, and as joint efforts with organizations possessing unique capabilities for human factors research. The research described in this report was done by personnel of the Human Resources Research Organization (HumRRO), under contract DAHC19-75-C-0025, monitored by personnel from the ARI Fort Hood Field Unit. This research is responsive to the special requirements of TCATA, the 1st Cavalry Division, 2nd Armored Division, and the objectives of RDTE Project 2Q763743A775, "Human Performance in Field Assessment," FY 77 Work Program.

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A STUDY OF SELECTED PROBLEMS IN ARMOR OPERATIONS

BRIEF

Requirement:

The work described in this report is that referred to in paragraph 2.2.2 of the Statement of Work (revised) dated 3 February 1977, under the title, "Effects on Tank Crew Performance of Special Hatches and Other Factors." The problems addressed were derived from the previous year's study of buttoned-up armor operations and from Human Resources Need (HRN) statements submitted by armor units at Fort Hood, Texas. The following objectives guided the work conducted:

- To determine the effects of external environmental conditions on the internal environment of a buttoned-up tank.
- To determine the kind and extent of training currently provided in escape and/or evacuation of wounded or injured personnel from armored vehicles; to obtain crewmen opinions concerning the adequacy of current escape and evacuation systems; and to determine what design changes crewmen feel should be made in escape and evacuation systems.
- To determine what factors influence tank commanders' target acquisition performance in the closed-hatch mode.
- To determine the problems involved in the development of Measures of Effectiveness (MOE) for tank crews, and to determine what research must be accomplished in order to develop a reliable, valid, and comprehensive set of MOE.

Procedure:

Work towards meeting each of the objectives was conducted independently. The procedures followed in each case are outlined below.

In order to determine how external conditions affect the internal environment of a tank, a recording hygro-thermograph was placed in an M48 tank. The tank was sealed, and data on internal temperature and relative humidity were obtained over a several day period in late summer. These data were then compared with comparable data obtained outside the tank.

Information on the kind and extent of training in escape and/or evacuation of wounded or injured personnel were obtained by a questionnaire. Thirty-three crewmen with some actual experience in escape and/or evacuation served as subjects. Opinion data were also obtained concerning needed design changes and the adequacy of current escape and evacuation systems.

Target acquisition performance of tank commanders operating in the closed-hatch mode was investigated in two experimental studies. Factors

examined included slew rates, cupola position, and the use of an aiming reference. Performance data under different conditions were obtained for each tank commander involved, and these data were compared to performance in the normal open-hatch mode.

A review of the relevant literature was conducted in an effort to determine the problems involved and the methods typically employed in the development of MOE for crews or larger personnel units. Extensive contacts were also made with other research personnel working in related areas. Based on the information obtained, a program of research was outlined aimed at the development of MOE for tank crews.

Principal Findings:

- Temperature and relative humidity inside a buttoned-up tank lag temperature and relative humidity outside the tank by approximately three hours.
- Effective temperatures inside a buttoned-up tank in warm weather reach levels that can be expected to degrade performance.
- Current training in escape and/or evacuation of injured or wounded personnel is extremely limited.
- If a tank is hit, the gunner is the most vulnerable crew member.
- Lifting straps built into a tankers' uniform would aid considerably in the evacuation of wounded or injured personnel.
- Target acquisition performance is not affected significantly by either slew rate, cupola position, or the use of an aiming reference.
- Target acquisition performance is not degraded in the closed-hatch mode.
- Techniques for derivation of MOE for crews or larger personnel units are not well developed.
- The only current work of any magnitude being conducted in the area of MOE for tank crews is concerned with gunnery.

Utilization of Findings:

The findings concerned with the relationship between external and internal environmental conditions, and the opinion data on escape and evacuation systems should be useful to tank designers in developing future tanks or in planning modifications to present tanks. Similarly, the recommendations on the need for lifting straps in tankers' uniforms should be of use to those charged with clothing design.

Training authorities should find the information on target acquisition both useful and comforting. With minimal practice, tank commanders can perform as well with closed hatches as with open.

The chapter on MOE will be useful in future developments of MOE for tank crews and platoons, in that the problems have been specified, and potentially fruitful approaches have been suggested.

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CHAPTER I

OVERVIEW

All research described in this report was conducted under a project titled, "Effects on Tank Crew Performance of Special Hatches and Other Factors." However, each of the four chapters deals with a totally different problem. For example, Chapter II is concerned with the effects of external environmental conditions on the internal environment of a tank with hatches closed. The need for this work was prompted by inferences drawn from an extensive review of the literature concerned with potential problems involved with extended armor operations in the closed-hatch (buttoned-up) mode.¹

Chapter III is concerned with escape and/or evacuation of wounded or injured personnel from armored vehicles. This effort was initiated as a result of a concern expressed by personnel of the 2nd Armored Division. They felt that hatch design might have to be modified, and/or, that special training in these subjects might be required to ensure confidence of tank crewmen in their safety.

Chapter IV describes studies of target acquisition by tank commanders under various conditions. In this study, "acquisition" refers to the act of laying the main gun reticle on the target after the target has been "detected." This effort was prompted by interviews with test officers who participated in a TRADOC Combined Arms Test Activity (TCATA) test of closed-hatch operations, and from reports in the literature commenting on terrain and target disorientation while operating with the

¹W. L. Warnick, A. L. Kubala, J. L. Maxey, and W. H. Ton. *Study of the Psychological (and Associated Physiological) Effects on a Tank Crew Resulting From Being Buttoned Up*, ARI Research Problem Review 76-13, Human Resources Research Organization, and Army Research Institute, October 1976.

hatches closed. The commanders reported frequent spatial disorientation while slewing the turret to the target location. The chapter describes two small studies oriented toward a better definition and a remedy for this problem.

Chapter V discusses problems associated with the development of Measures of Effectiveness (MOE) for tank crews, and outlines needed research in this area. This effort was conducted as part of a larger ongoing effort on the development of methodologies for evaluating unit effectiveness under operational conditions.

Because of the diversity of topics, each chapter is essentially a complete report in itself. The reader interested in a particular chapter need not read the preceding chapters in order to understand the material presented. Also, for the benefit of readers not interested in all of the topics covered, the appendixes and references cited for each chapter are presented separately at the end of each chapter.

Chapter I

LIST OF REFERENCES CITED

(All references are unclassified.)

Warnick, W. L., Kubala, A. L., Maxey, J. L., and Ton, W. H. *Study of the Psychological (and Associated Physiological) Effects on a Tank Crew Resulting From Being Buttoned Up*, ARI Research Problem Review 76-13, Human Resources Research Organization, and Army Research Institute, October 1976.

CHAPTER II

DETERMINATION OF THE EFFECTS OF EXTERNAL TEMPERATURE AND HUMIDITY ON THE INTERNAL ENVIRONMENT OF A TANK

Background

Heat and humidity are likely to cause degraded human performance if it is necessary to operate tanks with hatches closed for extended periods of time. However, there is very little published research on the effects of heat and humidity on armored vehicle crews. This lack of information is probably due to the fact that current strategic thinking emphasizes the possibility of fighting Warsaw Pact forces in the relatively cool areas of central and northern Europe.

A recent review¹ of the literature dealing with the effects of heat and humidity on human performance showed that:

- Tasks which do not require great physical effort are little affected until Effective Temperature (ET)² exceeds 90°F. However, if tasks requiring some physical exertion are performed, effectiveness decreases above about ET 85°F, and casualties may be expected with ETs of 85°F or higher.
- Specifically, the upper limit for tolerance of heat in tanks seems to lie between ET 88°F and ET 92.5°F.
- A Wet Bulb Temperature (WBT) of 91°F or above results in decreased alertness.
- The "comfortable" range for humidity is between 40 and 60 percent.

¹W. L. Warnick, A. L. Kubala, J. L. Maxey, and W. H. Ton. *Study of Psychological (and Associated Physiological) Effects on a Tank Crew Resulting From Being Buttoned Up*, ARI Research Problem Review 76-13, Human Resources Research Organization, and Army Research Institute for the Behavioral and Social Sciences, October 1976.

²ET = Temperature Humidity Index = .4 (Dry Bulb Temperature + Wet Bulb Temperature) + 15. (See E. J. McCormick, *Human Factors Engineering* (2nd ed.), New York: McGraw-Hill, 1964.

- Acclimatization to heat takes from 3 to 12 days, and is more effective if the individual exerts.

Both the British and German armies explored the effects of high temperatures on the performance of tank crews during WWII, and found evidence of considerable performance degradation.

A few studies have been done recently on some aspects of the problem. Suarez³ found that the summer daytime Wet Bulb Globe Temperature (WBGT)⁴ inside an M60 tank varied from 100°F to 106.6°F. No crew was present in the tank, so nothing was reported concerning the effect of these temperatures on crew performance. However, it was noted that these WBGT levels were much higher than is considered acceptable for human working conditions. The presence of a crew would have caused these WBGT levels to have been even higher, because of increased humidity which would raise the WBT levels.

Fenning, et al.⁵ recommended that thermal radiation from tank walls be studied. Tank walls will be heated by both radiant and ambient heat from the exterior environment. The tank walls will then radiate heat to the interior atmosphere and to any objects or persons in the tank. Radiated heat may, therefore, contribute substantially to the discomfort

³J. Suarez. *Methodology Investigation of Armored Fighting Vehicle Compartment Temperatures, M60 Tank*, USAPG Report No. 203, US Army Yuma Proving Ground, Arizona, November 1974.

⁴WBGT = .1 Dry Bulb Temperature + .7 Wet Bulb Temperature + .2 Black Globe Temperature. Black Globe Temperature is a measure of radiant heat.

⁵W. Fenning, P. Jackson, and R. Kelley. *Reference Sources in the Physiology of Extreme Environmental Temperatures*, Engineering Research Institute, University of Michigan, Ann Arbor, May 1954.

of the tank crew, and if ETs of 90°F or above are reached, degraded performance and casualties from heat stress are likely. Conversely, in cold climates the tank walls will lose heat to the exterior environment and when the tank walls are cold, the crew inside of the tank may lose a good deal of body heat by radiation to the cold tank walls. Cold is likely to be less of a problem than heat, however, because clothing can be worn to conserve body heat.

No studies were found which dealt with the effects on human performance of wearing Nuclear, Biological, and Chemical (NBC) protective gear in a closed environment, such as a tank with hatches closed. NBC protective gear would greatly increase the risk of heat stress for tank crews operating with closed hatches in a hot climate, and probably also in temperate climates.

Altogether, it is clear that there is very little information available concerning crew performance under closed-hatch, NBC conditions. If continuous armor operations are to be feasible, much more information is needed on this problem.

Military Problem

The concept of continuous or sustained operations for armor has been considered seriously only recently. The development of night vision devices of various kinds, and the recent emphasis on combat system reliability have made the concept of continuous armor operations feasible. Continuous operations will make greater demands on the soldiers who man armor forces.

In addition to the greater demands on human endurance posed by continuous operations, demands for stamina will also result from the likely

necessity of operating in the closed-hatch mode for substantial periods of time in any future war. Two factors indicate this necessity. First, the stated doctrine of potential enemies dictates the employment of NBC weapons, if required. Threat forces habitually train for combat under these conditions. Second, threat forces are expected to employ massive amounts of artillery. US armor forces are expected to fight outnumbered under these conditions, and still prevail on the battlefield.

During closed-hatch operations, the internal environment of a tank will have major effects on the crew's ability to function effectively. Specifically, the temperature and humidity inside a buttoned-up tank will be vital factors in determining whether the crew can carry out their duties effectively. Therefore, it is important to investigate the effects of external climatic factors on the internal environment of a tank.

Research Problem and Design

This study was aimed at determining the relationships between external temperature and humidity and the internal environment of a tank. In order to obtain data for a baseline condition, measurements were made without the tank engine operating, and without a crew in the tank.

Instruments for measuring and continuously recording Dry Bulb Temperature (DBT) and Relative Humidity (RH) inside the tank were obtained from the Army Scientific Laboratories Meteorological Team (ASL Met Team) at TCATA, Fort Hood, Texas.

Permission to use an M48 target tank for measurement purposes was obtained from HQ, TCATA. The tank was parked in the open in a motor

pool at West Fort Hood. All broken vision blocks were sealed with cardboard and heavy masking tape. The ASL Met Team then installed a hygro-thermograph recorder inside the tank. Continuous temperature and humidity measurements were recorded on a hygro-thermograph chart.

The temperature and humidity inside the tank were continuously recorded from 1400 hours on 12 August 1976 through the morning of 19 August 1976. External temperature and humidity readings were recorded by the ASL Met Team hourly from 0700 until 2000 each day during this period and reported on standard Weather Bureau forms.

Results and Conclusions

In Figure II-1 it can be seen that the rise in internal temperature of the tank lags the external temperature for a substantial part of the day, from shortly after 0900 until about 1530. After 1530 the internal temperature continues to rise, while the exterior temperature begins to drop, particularly after 1700. The amount of this lag remains nearly constant between about 1000 and 1400 at a little more than 1.5 hours. It should also be noted that temperatures inside the tank rise in the early evening to well above 90°F. Further, at no time did internal temperatures fall to a level that would be comfortable for persons engaged in heavy physical activity.

The time lag in internal temperature change, compared to external temperature change, can be explained by the thermal inertia of the tank hull. Because of its bulk, the tank hull is warmed more slowly than the external air during the early part of the day, and thus insulates the inside of the tank to some degree. However, the tank hull is warmed as the day goes on (mainly by the radiant heat of the sun) to temperatures

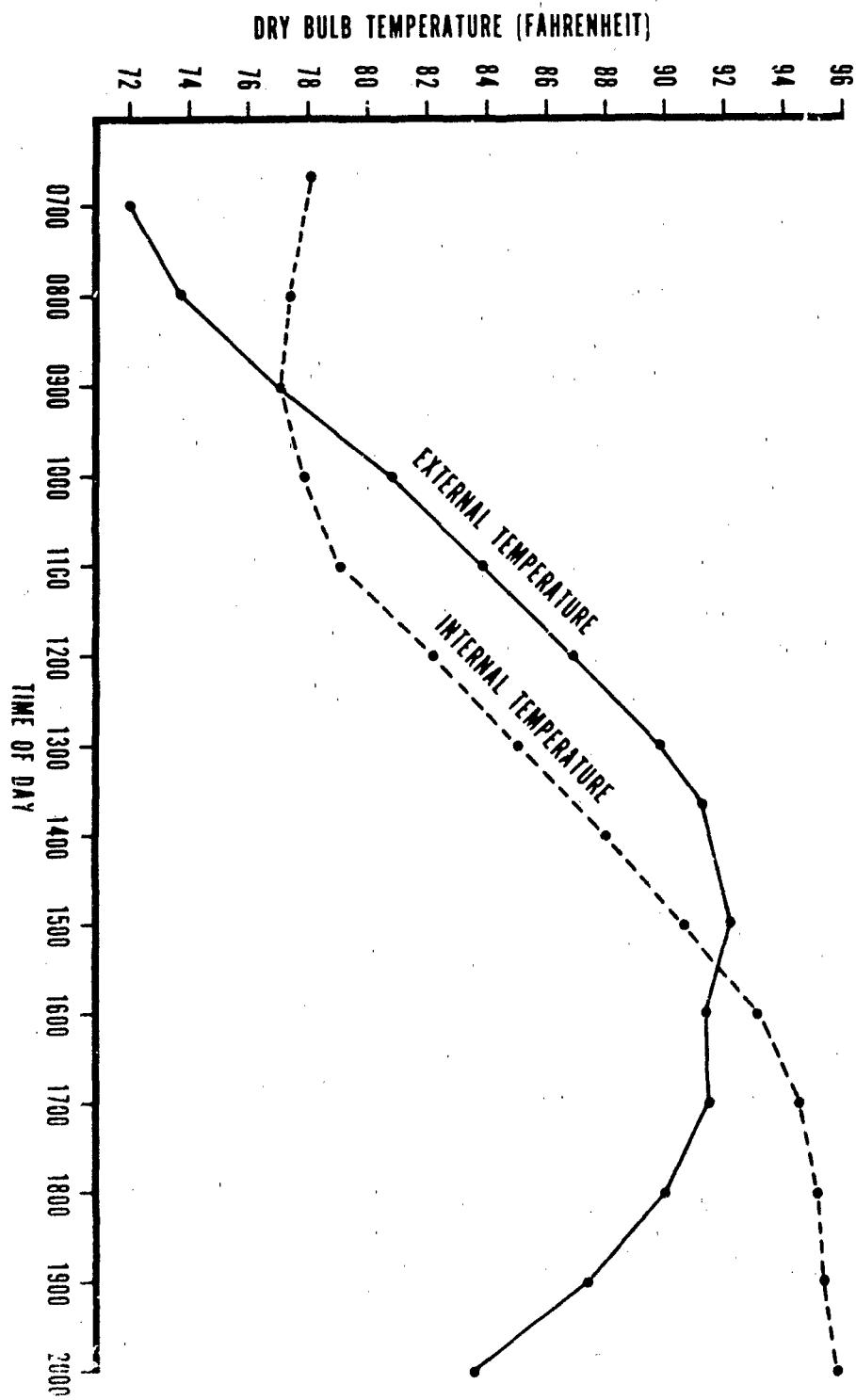


FIG. 11-1. Comparison of external and internal temperatures (means), 12-18 August 1976.

considerably above those of the external air. Then in the early evening the hot mass of the tank hull continues to radiate heat to the air and objects inside the tank, so that internal temperatures continue to rise until long after the external air temperature has started to drop.

Figure II-2 shows a comparison of external and internal relative humidity. Again, the internal measurements lag the external measurements for a substantial part of the day. However, the drop in relative humidity as the day goes on is almost entirely a function of the increase in temperature, so Figure II-2 tells us almost nothing beyond what we learned from Figure II-1. The relationships between temperature and relative humidity are shown graphically in Figures II-3 and II-4; Figure II-3 for the tank's internal environment, and Figure II-4 for the external environment for the period from 0700 to 2000. Figure II-5 shows the relationship between temperature and relative humidity for the internal environment for the entire 24-hour period.

Figure II-6 presents external and internal ETs. The ETs were computed using the following formula: $ET = DBT - (.45 - .55 RH) (DBT - 59)$ ⁶. In Figure II-6 it can be seen that internal ET lags external ET in much the same fashion as internal DBT lags external DBT.

Since ET is an index of discomfort, based on empirical data, Figure II-6 gives the best information on the probable effects of temperature and humidity on tank crew performance. Duke, *et al.*,⁷ in a comprehensive review of heat stress, found great consistency in experimental results:

⁶McCormick, *op. cit.* (see footnote #2).

⁷M. J. Duke, N. Findikyan, J. Anderson, and S. B. Sells. *Stress and Heat II. Thermal Stress-Heat*, Technical Report No. 11, Institute of Behavioral Research, Texas Christian University, Fort Worth, May 1967.

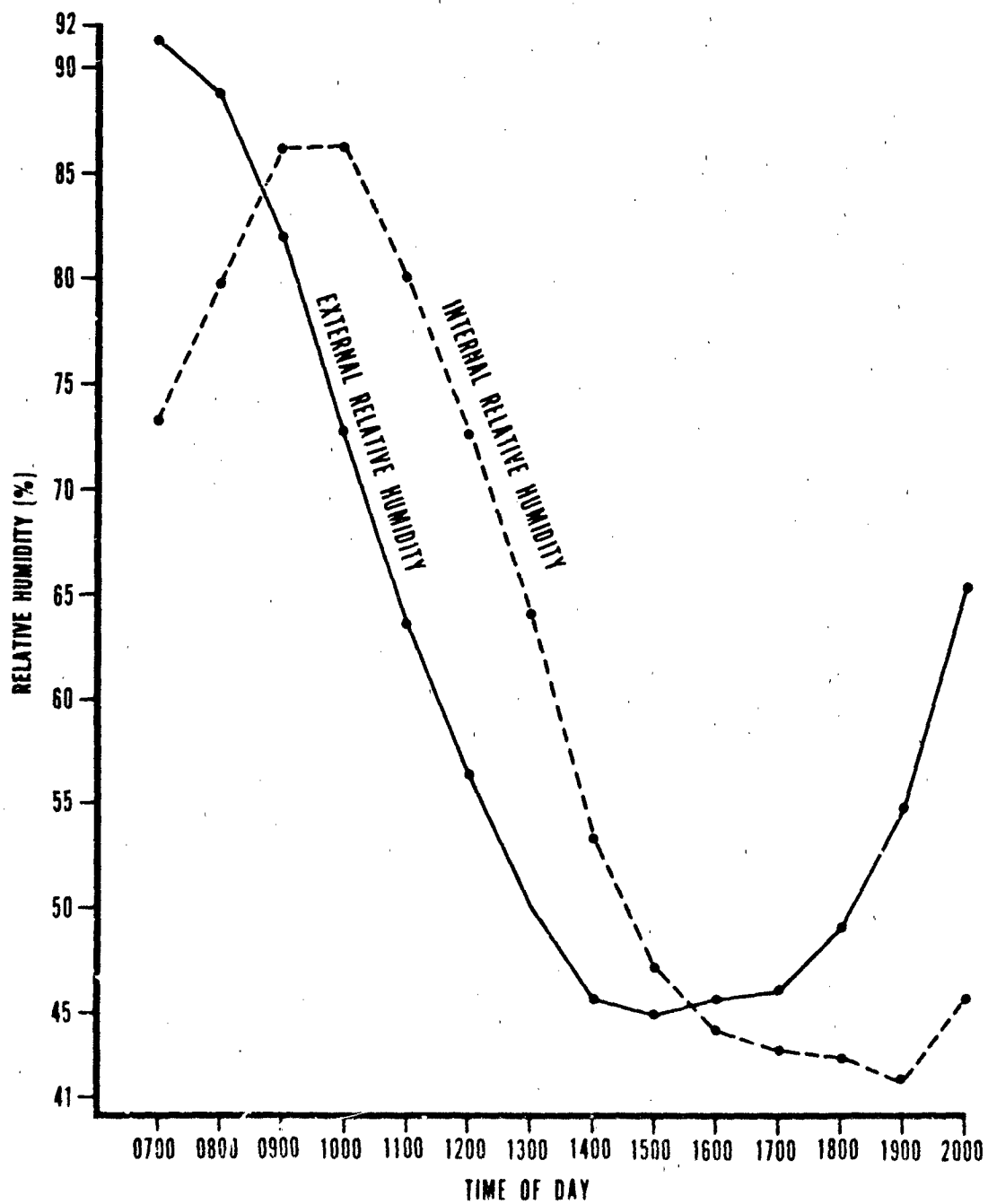


FIG. II-2. Comparison of external and internal relative humidity (means), 12-18 August, 1976.

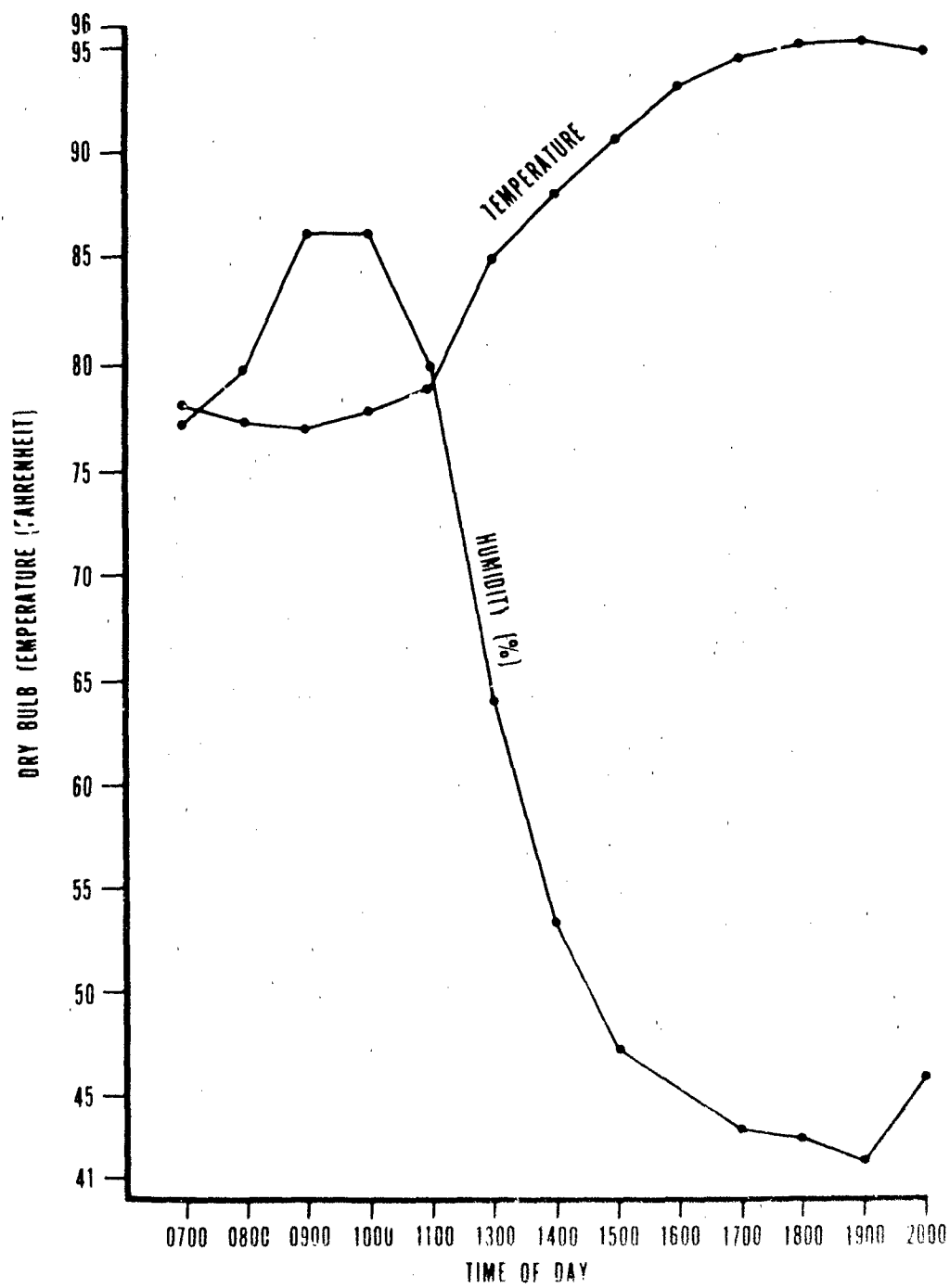


FIG. 11-3. Relationship of internal temperature and relative humidity (means), 12-18 August, 1976.

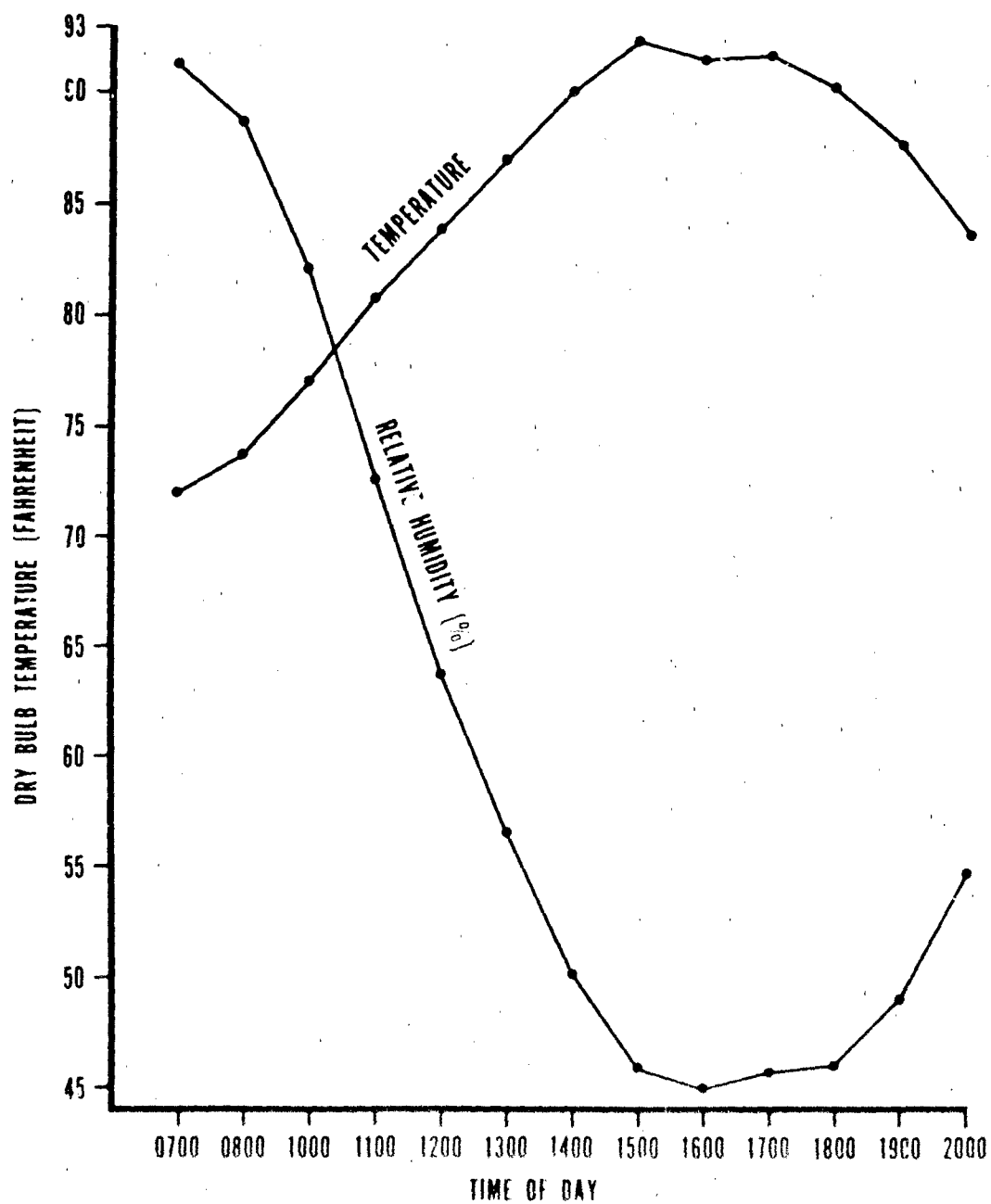


FIG. 11-4. Relationship of external temperature and external relative humidity (means), 12-18 August, 1976.

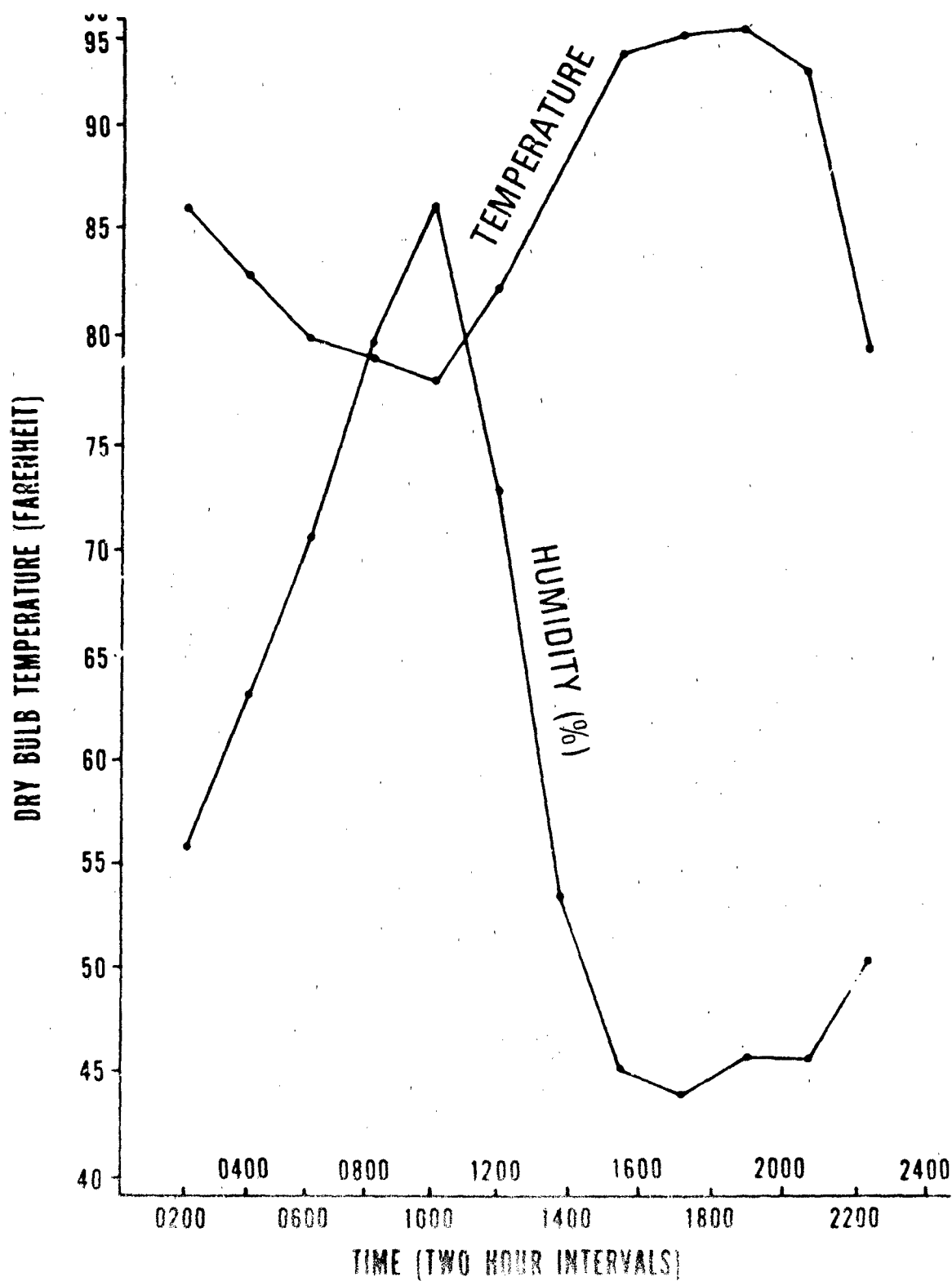


FIG. II-5. Comparison of internal temperature and internal relative humidity (means), 12-13 August 1976.

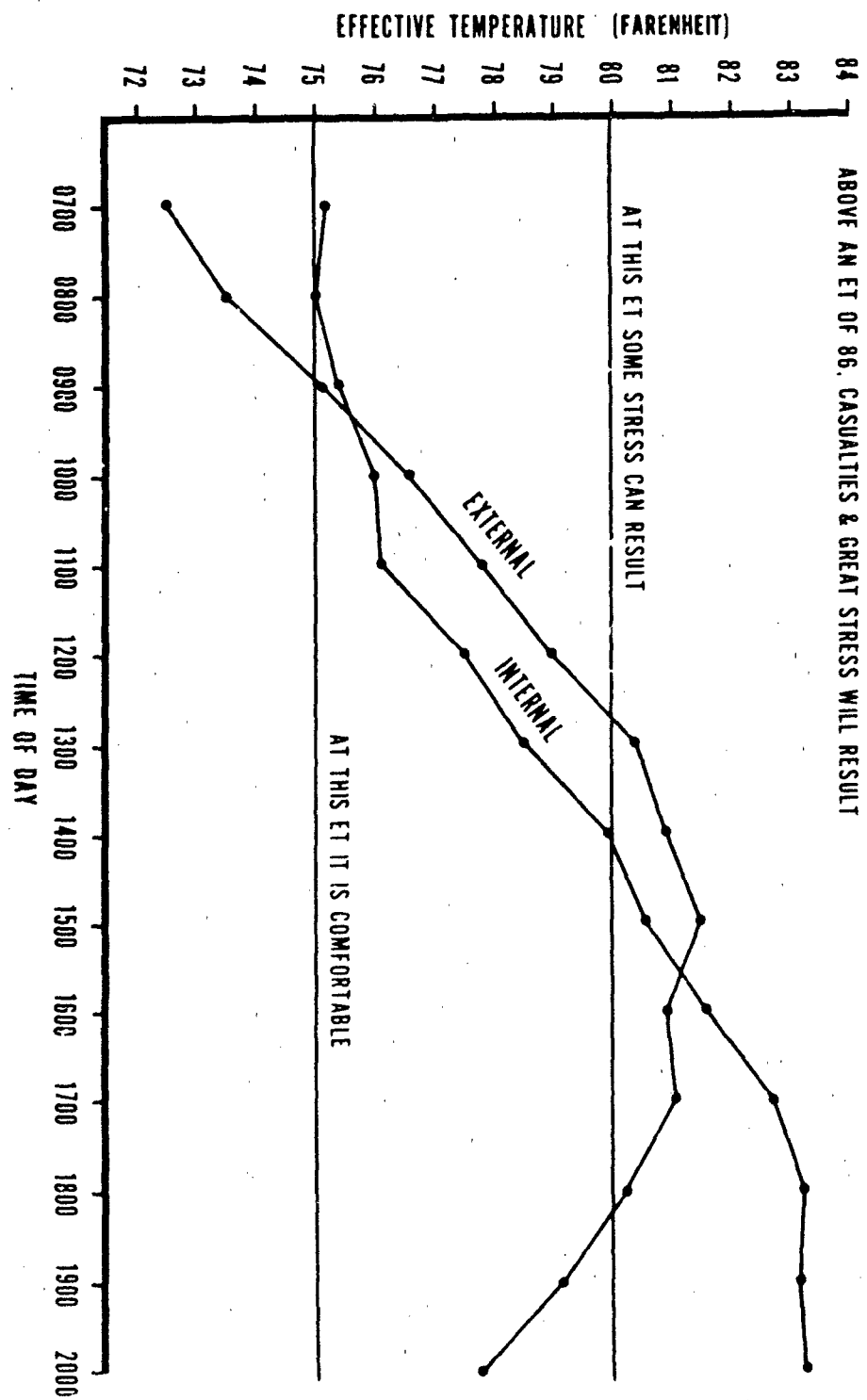


FIG. 11-6. Comparison of external and internal effective temperatures (means), 12-19 August, 1976.

an ET of 75° is comfortable, and ET of 80° results in some distress, an ET of 85° produces great distress, and ETs above 86° result in casualties. From Figure II-6, it is apparent that ETs rise to the uncomfortable range by early afternoon and remain in this range for many hours.

The internal ETs shown in Figure II-6 were measured without a crew in the tank, and without the tank engine running. Both of these factors would tend to raise the temperature (DBT) in the tank, and in addition the presence of a crew would raise the humidity through respiration and perspiration.

The increased humidity that the presence of a crew will probably contribute in a buttoned-up tank can be estimated from a series of studies carried out by Hicks,⁸ with Armored Personnel Carriers (APCs) under closed-hatch conditions. He found that in occupied APCs, condensation on the interior surfaces of the vehicle was a major problem. The condensation occurred in the early morning hours when the walls of the APC had cooled. Occupants found that leaning against the walls of the vehicle caused their clothes to become wet. Condensed water dripped from overhead surfaces onto clothing and other gear stored in the vehicle. Some of the gear began to rust. Also, vision blocks became fogged, which would have made combat operations very hazardous.

Thus, it seems clear that ETs in a tank operating buttoned up under hot, humid climatic conditions would be substantially higher than those

⁸S. Hicks. *The Effects of Confinement on the Performance of Combat Relevant Skills, Summary Report*, Technical Memorandum 16-64. US Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland, 1964.

obtained in this study, and almost certainly up in the critical range above 86°. Kennedy, et al.,⁹ point out, in the context of shelters against nuclear weapons effects, that humidity will approach 100 percent and temperatures will rise well above 80° in a crowded shelter in a few hours. If the effects of external temperatures well above 80°, are added to this, along with the heat generated by the tank engine, and some degree of exertion by the tank crew, ETs in the tank will certainly rise into the critical range. Kennedy, et al., recommend ventilation and a minimum of 15 cubic feet per occupant if external temperatures exceed 80°F. How to implement these recommendations for tank crews poses a real challenge to designers.

⁹ T. Kennedy, B. Hoot, J. Ball, and P. Rieck. *Expedient Field Fortifications for Use Against Nuclear Weapons*, Final Report, Technical Report N-74-7, US Army Engineer Waterways Experiment Station, Weapons Effects Laboratory, Vicksburg, Mississippi, September 1975.

Chapter II

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CHAPTER III

SPECIAL HATCHES STUDY: ESCAPE AND EVACUATION OF WOUNDED PERSONNEL FROM TANKS

Part I: Background, Problem and Approach

Background and Military Problem

The basis for the initiation of this investigation was a Human Resources Need (HRN) submitted by the 2nd Armored Division (2nd AD), Fort Hood, Texas, for research into "tank escape systems."

The concern of the 2nd AD was based on experience by some of their personnel during the Vietnam Conflict in which the enemy successfully employed Rocket Propelled Grenades (RPGs) against US armored vehicles. RPGs and secondarily antitank mines constituted the most critical threat to tanks and Armored Personnel Carriers (APCs). The capability of newly developed antitank weapons are capable of penetrating almost any existing tank. The proliferation of these weapons, down to the level of the individual soldier, indicates a need for a critical examination of tank escape systems.

A second, but highly related concern is the evacuation of a wounded or injured crewman from within the tank. At present, it is extremely difficult to remove an unconscious or physically disabled crewman due to the limited internal space and small size of the hatch openings. Evacuation of the driver is extremely difficult if the turret drive system is disabled with the turret in the forward position. The injured driver must either be lowered to the ground beneath the tank through the driver's escape hatch, or moved into the turret, and removed through either the

loader's or tank commander's hatches. Tank designers appear to have given little consideration to evacuation requirements.

In discussions with 2nd AD personnel, a further concern was expressed over reports that some tank units did not use a gunner during the Vietnam Conflict. In this case, the main gun was fired from the commander's position. Personnel of the 2nd AD hypothesized that the elimination of the gunner was due to a feeling that his performance could be adversely affected by his vulnerability to enemy antitank weapons. The tank gunner, more than any other crewman, is vulnerable to enemy fire penetrating the turret wall. Furthermore, of current US tanks only the M60A2 provides the gunner with his own hatch. Therefore, in most tanks, he is almost certain to be the last man out if the crew is forced to escape. This concern over this possible elimination of the gunner due to his vulnerability lent impetus to 2nd AD's interest in tank escape systems. They felt that it was necessary to determine the requirements for and cost effectiveness of changing tank designs and/or modifying existing tanks to improve chances of escape. In addition, they felt an investigation should be made into the possibility of developing training programs intended to overcome the disadvantages of current tank design.

Although not specifically addressed by the 2nd AD, another related problem is the rescue of wounded ground personnel by the tank crew. During WWI, this means of rescue was not uncommon. The tank would be positioned over the wounded soldier so as to protect him from further enemy fires, and he would be lifted into the tank through the driver's escape hatch. Such an operation would be extremely difficult in our M60

series of tanks, as the driver's escape hatch is located almost directly under the driver's seat. Work space in the driver's compartment is extremely limited, and the driver would obviously be unable to move the tank until the wounded soldier was removed to the turret and the seat reset.

Research Problem and Approach

At the outset, virtually nothing was known about any previous work on escape and/or evacuation, about the amount or kind of training crewmen receive(d) on these subjects, nor about crewmen's attitudes concerning the adequacy of current escape systems and any associated training programs. Therefore, as a first step, it was necessary to determine what work in the area had been accomplished, and what work, if any, was in progress. To this end, a survey of the literature was conducted, and knowledgeable personnel in a number of both military and civilian agencies were contacted.

The second step was the development and administration of a questionnaire to armor personnel with actual experience in escape and/or evacuation from armored vehicles. The questionnaire was designed primarily to obtain information relevant to the 2nd AD's concern, taking into account the information obtained from the literature survey and other workers in the armor field. The decision to survey only personnel with first-hand experience in escape or evacuation was based on the notion that their experience would allow them to make an informed judgment concerning escape and evacuation needs. Those without such experience might have given the subjects little previous thought, and their speculations would likely only add "noise" to the results.

The results of the effort outlined above are reported below in two parts. Part II deals with the attempt to garner all of the currently available information on escape and evacuation. Part III deals with the administration and findings of the questionnaire, and presents a brief summary of the overall effort.

Part II: Results of the Information Survey

Personal Contacts

Personnel involved in the development and/or testing of tanks and associated systems were contacted in the Armor School, Fort Knox, Kentucky, the ARI Field Unit at Fort Knox, the HumRRO office at Fort Knox, the Human Engineering Laboratories (HEL), and the Chrysler Defense Corporation. The results were disappointing. So far as could be determined, there was no ongoing work concerned specifically with escape or evacuation, nor was any planned in the foreseeable future. A number of incidental items of information were obtained, but they were largely irrelevant to the objectives of this research. The only relevant information came from conversations with personnel at the ARI Field Unit at Fort Knox.¹ It was ascertained that training materials were being prepared by the Armor School for crew drills which include escape and evacuation. The task, conditions, and standards for for each type of drill and the procedures for each member to follow are being specified. These drills are now in draft form and are planned for publication sometime during the summer of 1977.²

¹Personal communication from Dr. R. T. Bauer, ARI Field Unit, Fort Knox, Kentucky, March 1977.

²Personal communication from CPT Dale Stewart, Directorate of Training Development, US Army Armor School, Fort Knox, Kentucky, March 1977.

The only conclusion that could be drawn from these personal contacts was that there was little interest in escape or evacuation in the research and training communities associated with armor.

Literature

The primary sources consulted in conducting the literature survey were the Defense Documentation Center (DDC) and the Engineering Abstracts. Again, the results were disappointing. A search of the Engineering Abstracts for the previous five years revealed only information concerned with escape and evacuation from submarines and aircraft. Examination of some of these reports proved them to be irrelevant to the armor problem. Despite an intensive search employing a wide variety of Identifiers, only three reports of relevance were located in DDC. Only one of these was actually concerned with crew escape from a tank in an emergency. Because of the meagre literature on the subject, each of the three relevant reports located will be reviewed in some depth.

An investigation by Dickinson and Horley³ compared crew escape times from the proposed MBT 70 under various emergency conditions to escape times for the M60A1 tank. The proposed MBT 70 design necessitated moving the driver's escape hatch from the front of the hull (as in the M60A1) to a central location under the turret. This move became necessary because the driver, gunner, and tank commander were all to be located within the turret. The Dickinson and Horley study consisted of two parts. Part I determined the crew's tactical emergency-escape

³N. F. Dickinson and G. L. Horley. *US/FRG MBT-70, Crew Emergency Escape Study*, Technical Note 6-68, US Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland, March 1968.

capabilities from the MBT 70 under the worst and best conditions for turret azimuth position, and compared these results to similar conditions in the M60A1 tank. Part II investigated the feasibility of escape through the bottom escape hatch, should the tank be upset. In addition, the investigators examined the ease of gaining access to the interior of the MBT 70 from the outside through the escape hatch. Access from the outside would be important in the event the tank overturned. In this instance, it might become necessary to gain access to evacuate wounded or injured personnel. A similar investigation was not made with the M60A1 tank as the escape hatch is not designed for removal from the outside.

The investigators initially found that the MBT 70 emergency escape system was not workable. They then modified the escape system and the data presented in the study basically reflects escape with their modified MBT 70 system. They compared escape times only through the escape hatch in the bottom of both tanks. No escape times were collected for exits through the other hatches. The crew participating in the study carried their personal weapons (M3 submachinegun, caliber .45 pistol) and wore the typical tanker gear (CVC helmet, combat boots, etc.).

Crew mean escape times from the M60A1 averaged 59.2 seconds under the worst condition and 24.1 seconds under the best condition. Under the worst condition, the position of the turret caused ammunition for the main gun to block access by turret personnel to the driver's escape hatch.⁴ The escape hatch in the M60A1 is located directly under the driver's position. The loader needed a mean time of 32.0 seconds to

⁴ It was assumed that under the worst condition that the turret was disabled, and therefore could not be rotated. In the best condition, it was assumed that the turret was either in the best position or could be rotated into this position.

remove the rounds before turret crew members could gain access to the escape hatch.

Timing of escape from the M60 in the best position commenced after the turret was rotated 180°. This movement resulted in unobstructed access to the escape hatch by turret crewmen. If timing had started with turret movement, the mean times to escape would be inflated by the time required for the turret to traverse (31.6 seconds instead of the 24.1 seconds reported).

Escape times for the centrally located MBT escape system were 65.2 seconds for the best and 88.0 seconds for the worst conditions as dictated by the position of the turret. As can be seen, these times compare very unfavorably with the times reported for the M60A1.

Dickinson and Horley cautioned that under tactical conditions in forward areas during a silent-watch mission, an escape hatch which could be opened from the outside could be released by the enemy without the crew's knowledge. However, the present authors feel that the provision of outside access has merit, especially when the crew is injured or when the turret is in a position to prevent the crew from releasing the escape hatch. A simple anti-intrusion/tamper device could alert the crew to the enemy presence under the silent-watch condition.

The Dickinson and Horley report provides guidelines for the design of future tank escape systems. They point out that if a tank escape system permits personnel outside the tank to rescue the crew, the system must not require special tools or equipment. This equipment will probably not be readily available under tactical or even training conditions. As regards training, Dickinson and Horley noted that efforts must be

made to ensure that practice in escape does not damage operating equipment. The MBT 70 escape system created potentially troublesome problems for maintenance. MBT crews were required to remove a slip-ring in the turret for each escape exercise. The slip-ring was generally damaged by removal, which could have caused its failure and a malfunction of the overall turret control system.

One of the design requirements for the MBT 70 tank was to provide crew members with safety devices such as seat belts and shoulder harnesses. These devices were intended to minimize injury to a crew in case the tank rolled over. No US tank in current use has provision for safety harnesses or seat belts at any of the crew stations. Dickinson and Horley point out that if restraining devices are considered for future use, they must be designed so that no crew member could be trapped or impeded in escaping quickly from the tank in an emergency. They should also be designed so that personnel evacuating wounded or injured crew members could easily and quickly unfasten the restraining device.

In an older but still relevant study, Williams⁵ evaluated the effects of fire bombs dropped by aircraft against the T26E4 tank. It was concluded that after being hit it would have been possible for the crew to evacuate the tank immediately, or, if conditions dictated, to have waited five minutes for the fire to subside before evacuating. The crew could then fight the fire and probably remount and continue as an effective unit. This investigation is cited to point out that a tank crew may have to evacuate (escape) in order to protect and save their weapons system, and not just for survival.

⁵ J. R. Williams. *Terminal Ballistic Tests of Fire Bombs Against the T26E4 Tank*, Report No. 770, Ballistic Research Labs, Aberdeen Proving Ground, Maryland, June 1951.

Reeves and Vikestead⁶ did not directly study escape systems. However, some of their conclusions and recommendations should be considered when planning and designing escape systems. For example, they concluded that the greatest hazard to the crew is the potential for explosion or fire created by the storage of main gun ammunition and fuel in the crew compartment. These items are particularly hazardous due to the crew's confinement and difficulty of escape. Reeves and Vikestead point out that compartmentalization of fuel and ammunition and isolation of these items away from the crew compartment should considerably reduce casualties.

These authors also felt that the spall (metal ejected from the inner surfaces of the tank when hit) created by mines, large caliber kinetic energy projectiles, or heat projectiles was also a major hazard. They recommend the placement of ballistic cloth blankets in the crew compartment. This measure should minimize casualties from spall or from fragments of penetrating projectiles. The addition of spall liners to the interior walls and floor should also be considered. All of their recommendations, if implemented, should greatly reduce any crew anxieties concerning their own safety and survival.

The only concrete suggestions concerning the configuration of escape hatches for tanks were found in the Military Standardization Handbook.⁷ This publication stated that "...escape-hatch dimensions

⁶ H. J. Reeves and W. S. Vikestead. *General Principles for Vulnerability Reduction of a Main Battle Tank*, BRL Memorandum Report No. 23-21, USA Ballistics Research Labs, Aberdeen Proving Ground, Maryland, August 1973.

⁷ MIL-HDBK-759. *Military Standardization Handbook, Basic Factors Engineering Design for Army Materiel*, US Department of the Army, 12 March 1975.

should be based on three factors: (a) the work area personnel must escape from, (b) the equipment and clothing they will be wearing, (c) the environment they will enter." General guidelines to escape hatch design were:

- Hatches should open with a single motion of the foot or hand.
- Operating force should be less than 50 pounds for handles or pushbuttons.
- Hatches placed overhead should weigh less than 50 pounds and should be opened by force of gravity.
- Rectangular hatches should be a minimum of 16 x 24 inches with 20 x 28 inches preferred.
- Square hatch openings should be a minimum of 18 inches with 22 inches preferred.
- Circular hatch openings should be a minimum of 22 inches with 28 inches preferred.
- Floor mounted escape hatches should not be obstructed by seats or other equipment and locking and unlocking mechanisms should operate with 30 pounds or less of force.
- Floor mounted escape hatches should be at least 22 inches in diameter and should have at least 18 inches of clearance from bottom of the hatch to the ground.

Some of the more relevant general guidelines concerning access to hatches are cited for designing crew stations in combat vehicles.

- There should be adequate handgrips and footsteps to help the crew reach the hatches easily and safely from the ground. (Unfortunately, in tanks the only footholds are the front towing pintles and in some units they were removed so they would not be stolen or lost. Mounting on the side of the vehicle is unsafe as the crewmen could be injured in the roadwheels if the vehicle was accidentally moved. No specifically designed hand-holds are provided on tanks, and individuals who are small have difficulty in mounting the tank.⁸⁾
- All hatches and doors should be large enough to admit fully equipped 95th percentile operators.

⁸⁾ Statements in parenthesis are the present authors'.

- There should be a clear path from each hatch to the crew position(s) it serves. Men in a hurry should not have to squeeze around obstacles, or avoid tripping over fire extinguishers, cables, or the like.

The guidelines incorporated in the Military Standardization Handbook are not intended to be mandatory, but are furnished to designers mainly for informational purposes.

Summary and Conclusions

The literature is as interesting for what it does not address as for what it does address. Expressed concerns over crew safety, including escape or evacuation, are quite limited and evidence of concern by tank designers is lacking. For example, from the little literature located, it can be concluded that:

(a) An escape hatch in the bottom of the hull is desirable in case the tank turns over, but it should be capable of being opened from the outside with no special tools, and should be equipped with some kind of anti-intrusion device. (Note that the Chrysler Defense Corporation version of the XM-1 as recently proposed does not have a bottom hatch.)

(b) Crew members should be equipped with safety devices such as harnesses or seat belts with quick-release features. (Note that no current tanks have these features.)

(c) Spall liners (ballistic cloth) should be provided to minimize injury in the event that the tank is hit. (Note that no current tanks have spall liners; the proposed XM-1 does.)

(d) Fuel and ammunition should be compartmentalized outside the crew compartment to reduce the hazard to crewmen. (Note that in current tanks ammunition is stored in the crew compartment. The XM-1 has compartmentalized main gun ammunition.)

(e) Hatches should conform in size and shape to those recommended in human engineering guides.

In addition, the present authors hold a number of conclusions not addressed in the literature. These concerns can perhaps best be expressed as a series of unanswered questions concerning tank escape systems. For example: How is escape and/or evacuation of wounded affected by the wearing of NBC gear?; What provisions should be made for escape during an emergency in deep-water fording?; and, What actions should a crew take after escaping from a disabled tank?

Other questions could be asked. Perhaps the most important question concerns the attitude of crewmen toward the adequacy of current escape systems. This question will be addressed in Part III of this chapter.

Part III: Analysis of the Escape and Evacuation Questionnaire

Introduction

At the outset it was realized that the proportion of tankers with personal experience in either escape or evacuation of wounded or injured personnel would be quite small, and that any one individual's experience was likely to be limited to one, or at most two, incidents. Therefore, it was realized that, aside from descriptions of verifiable incidents, most of the information obtained, even from experienced personnel, would necessarily be largely subjective opinion. However, opinion and attitude data should be quite valuable in planning training programs. For example, Smith and Cox⁹ found that orientation training was an effective

⁹ R. Smith, Jr., and J. Cox, Jr. *Methods of Psychological Stress Due to Radiation*, AFPTRC-TN-57-19, Personnel Lab, Air Force Personnel and Training Research Center, Air Research Development Command, Lackland AFB, Texas February 1957.

approach to alleviating fears associated with work in the nuclear field. They concluded that stress and anxiety could be reduced by providing a realistic orientation to the situation, and by training personnel to cope with emergencies. It seems likely that these same principles should be applicable in alleviating anxieties associated with escape and evacuation from tanks. Responses to a questionnaire designed to tap these anxieties will be useful in providing direction for the development of training to enable tankers to cope with their concerns. It should be noted, however, that opinions concerning the technical aspects of escape and evacuation systems probably cannot be taken at full face value. However, they should provide tank designers with some useful hypotheses for further consideration and testing.

With the above caveat in mind, a questionnaire was designed. Items were written to obtain information relevant to all of the expressed concerns of the 2nd AD. However, additional items were constructed based on information obtained from the literature and personal contacts. A copy of the final version is shown as Appendix A. The findings are summarized below.

Participants

Participants in the survey came from the following military units:

- (a) US Army Armor School (staff and students), Fort Knox, Kentucky,
- (b) Armor School Brigade, Fort Knox, and (c) 2nd Armored Division, Fort Hood, Texas.

Participation in the survey was limited to individuals reporting experience in escape from a tank or aiding in the evacuation of injured or wounded personnel, either in peacetime or during combat.

The total number of respondents participating in the survey was 33. The sample size was limited by a scarcity of individuals in the service with relevant experience. A few participants had no direct personal experience with escape or evacuation, but were included because of their stated personal familiarity with the escape problem and a desire to participate. The questionnaire was administered by HumRRO personnel during February and March 1977.

Personal data. Thirteen participants were officers, ranking from captain to lieutenant colonel. Twenty were noncommissioned officers; three E6s, thirteen E7s, and four E8s. Nine of the respondents were aged 20 to 29, seventeen, 30 to 39, and seven, 40 to 49. Average time served in the Army was 14.9 years, with an average of 12.9 years in the Armor Branch.

Experience in armor. Twenty-two of the respondents had actually served in tanks during combat, while 11 reported no tank combat experience. Respondents were not asked to report if they had non-armor combat experience. Two individuals saw extensive combat on the M113 ACAV vehicle, which was employed much like a tank in Vietnam. However, their responses were included in the non-combat category due to the marked design differences between the escape systems of tanks and APCs. The majority of the respondents (24) served in Vietnam with two indicating combat service with tanks in Korea. Most combat experience was gained in the M48A3 tank and the M551 airborne reconnaissance assault vehicle. Of tanks in the current inventory, the respondents reported greatest familiarity with the M60 series followed by the M551. However, respondents reported serving in a total of *16 different tank models*. Most

respondents reported experience as tank commander or gunner. Relatively few reported serving as a loader or driver.

Anthropometry. Each respondent was asked to indicate his body frame by stating his normal shirt size. It was thought an individual's size and weight would have some bearing on how he responded to questions concerned with getting in and out of confined spaces. The assumption was that individuals who were smaller in stature would indicate fewer difficulties with the present tank escape system than individuals of larger stature.

The median height reported by the group was approximately 5'11". When compared to the anthropometric data presented for Air Force cadets in the 1972 Human Engineering Guide to Equipment Design,¹⁰ this median height would place them in approximately the 75th percentile for height. Their height would place them slightly above the 85th percentile for Air Force gunners.¹¹ This comparison is relevant as Air Force gunners must operate in confined spaces much like tank crews. It is interesting to note that the respondents were generally taller and heavier than one would expect to find in a career field where much time is spent working in small, confined spaces.

As compared to the overall height of US Army personnel, the group's median height of 71 inches places it above the 80th percentile. According to MIL-HDBK-759,¹² the median height for the group is above the 75th

¹⁰ H. P. Van Cott and R. G. Kinkade (ed.). *Human Engineering Guide to Equipment Design* (rev. ed.), Washington, D.C.: US Government Printing Office, 1972.

¹¹ *Id.*

¹² MIL-HDBK-759, *op. cit.*

percentile for US Army armor crewmen (these anthropometric data were collected in 1966).

The median weight of 190 pounds for the group is above the 75th percentile for armor crewmen, while the median weight of 190 pounds places them at the 90th percentile compared to all Army personnel as reflected by the data collected in 1966. Fifteen participants reported a medium frame, whereas 11 had a large frame. Only four reported a small frame and two an extra-large frame.

Since the collection of anthropometric information was begun, the average soldier in each successive war has been taller and heavier. In apparent defiance of this trend, the amount of space allocated to the crews of fighting armored vehicles has become less and less. Space becomes even more critical with the addition of standard full combat dress or special cold weather clothing or NBC gear. For example, the effective height of an individual is increased by 2.65 inches when wearing the standard uniform. This uniform includes underwear, shirt, trousers, fatigues or shorts, socks, and steel helmet with liner. In addition, combat field clothing can add up to 18.6 pounds to an individual's weight. Winter clothing or NBC protective gear for armor crewmen will add considerably to this weight and bulk, thus compounding the problems of escaping and removing wounded or injured personnel from the interior of the tank.

Escape and Evacuation Experience

Escape training. Approximately half of the group received prior training on tank escape at some time in their armor service; the remaining half received no training in escape. Only two individuals indicated

they had received their training during the 1970s. Most of the training was received in the 1950s and 1960s. These periods coincide with the Korean and Vietnam conflicts. Apparently, escape training is emphasized only in times of war. Informal conversations with experienced tankers and discussion with training personnel indicate that current training in escape is, for all practical purposes, nonexistent.

Of the individuals who were trained in escape, the initial training was usually by the unit (company) cadre. This training consisted of an average of four hours of instruction. When the group was asked to estimate the total amount of training they had received in escape during their period of service, their responses ranged from one to 100 hours, and averaged eight to ten hours. This amount of time is small when compared to the average length in armor of 12.9 years. Fourteen individuals reported being trained to escape through the driver's escape hatch. However, two of the respondents receiving escape training indicated they did not receive training in exiting through the driver's escape hatch. Twenty-four of the 33 respondents indicated that the *training time for escape should be increased*, while eight felt it should be left as it is.

As part of their training, some armor crewmen were trained to rescue wounded ground personnel through the driver's escape hatch. The escape hatch would be dropped and the tank would be driven into a position over the wounded person. This type of rescue was employed if an individual was wounded and, due to heavy small-arms fire, could not be reached by other means. The tank, being impervious to such fire, could perform rescue operations in this manner. However, a rescue of this

nature was reported by only one of the respondents. In this instance, an M24 tank was used, which has the escape hatch located behind the bow gunner. Twelve of the respondents had been trained in this method, while 21 had not. With the tanks currently in the inventory, this method of evacuation is difficult to accomplish, as the escape hatch is almost directly under the driver's seat. With current tanks, a successful rescue would depend solely on the driver's ability to pull the wounded person into the vehicle, leaving the driving controls unattended.

Escape experience. Twelve of the respondents reported escaping from a tank during training and 10 during combat. Of the respondents who escaped during combat, the majority had to escape only once; four escaped twice, two escaped three times, and two escaped four times. One individual escaped four times from an M113 ACAV vehicle and another individual escaped three times from an M113 APC. The majority of the individuals who reported escape experience were tank commanders at the time. In 11 instances their vehicle was disabled by an enemy tank or antitank weapon, in seven instances the tank was hit by a mine, in three instances the tank was burning. One of the respondents indicated that his tank hit antitank mines on eight different occasions, but only once was it necessary to evacuate the crew. Another individual reported being hit three times by RPGs, on two of those occasions the crew escaped because of injured personnel.

Six individuals reported escaping during training once, while four escaped twice. Most of these were tank commanders at the time. Fire was the predominant reason for escaping during training, while a driving accident was the second most prevalent reason.

Evacuation training. Eighteen respondents reported receiving training in evacuation, while 15 received no training. Four respondents indicated the training took place from 1971 through 1976. The majority, however, received their training during the 1950s and 1960s. Only two respondents indicated that this training included emergency medical care or was conducted in conjunction with medical personnel. One respondent reported a personal experience of an accident in which the crew were thought to have broken backs. Based on this experience, this respondent instigated a training program with medical help and supervision. It seems unfortunate that it took an accident to reveal the need for tank crews to have some basic medical skills which would allow them to care for injured or wounded personnel until the arrival of competent medical help.

Training in evacuation was usually conducted by the unit (company/troop) cadre. Four respondents indicated they received their training by the unit cadre during Advanced Individual Training (AIT). The respondents reported receiving an average of four hours of training, with a range of one to 100 hours. Twenty-four of the respondents felt that the training in evacuation should be increased, while eight felt it should remain the same.

Evacuation experience. Sixteen of the respondents reported evacuating a wounded or injured crewman from a tank during training, while 17 reported the experience during combat. Approximately half of the total respondents reported aiding in evacuation. The group reported an equal number of accidents which required evacuation during training as in combat.

Attitudes and Opinions

Concerning survivability. Survivability in tanks is usually discussed in terms of weapon firing rates, engagement ranges, armor protection, and speed. Rarely is survivability discussed in terms of the difficulty in entering or exiting the vehicle. It is rarely recognized that the time it takes a tank crew to mount or dismount the tank could be critical, and that access should be considered important to crew and vehicle survivability. This section reports the opinions of the respondents about their intended actions if hit by enemy fire. These opinions are expressed in the most general terms, for it is impossible to evaluate every conceivable situation. In combat, the crew's survival is dependent upon specific factors which are too numerous to list.

When asked to rate their chances of escaping from a tank if it was hit, 13 indicated that their chances were "not too good" and one indicated "no chance at all." Eight felt that their chances of escape would be about "average." Eight felt they had a "fairly good" chance, and only two felt they had an "excellent" chance of escaping. The group was also asked to estimate, as a percentage, their chances of successfully escaping from a disabled tank. Approximately half of the respondents rated the probability of successful escape as 50 percent or less.

The respondents were unable to rate each crew member's survivability under different locations of penetrations of the tank with different ammunition. (See question 20, Appendix A.) Percentages varied widely and there seemed to be no consensus among the respondents.

Concerning threats to crewmen. Respondents were asked to rank order possible threats. Their responses showed that the most feared

threats were: enemy tanks, antitank missiles, antitank guns, antitank mines, and being trapped by fire. Napalm, aerial bombs, rockets, and artillery were ranked lower, and "turning over in the tank" was ranked last. Table III-1 lists the types of threats. (Some not in the original list were added by the respondents. These are indicated by an asterisk.)

Table III-1
Types of Threats

Enemy Tanks	Aerial Bombs and Rockets
Antitank Missiles (includes RPGs)	Tank Ammunition Exploding
Antitank Guns	Tank Turning Over
Antitank Mines	*Hydraulic Fluid and Fuel Exploding
Napalm	*Drowning During Fording
Artillery	*Accidents From Terrain

*Responses not given in original list on questionnaire.

Concerning escape hatches. Only one hatch on the tank -- the driver's escape hatch -- is truly an escape hatch. The other hatches are provided mainly for routine access to the interior of the tank. For purposes of general discussion in this report, however, all hatches will be considered escape hatches.

When asked if they could escape quickly through the hatches of current tanks, 22 respondents felt they could, while 11 felt they could not.

The respondents were asked to rate the difficulty of escaping from each particular crew position. The ratings were to be based on no

particular tank model. The ratings are presented in Table III-2. This question was prompted by concern for the vulnerability of the gunner during combat. As is obvious from the table, the gunner is considered by far the most vulnerable.

Table III-2

Escape Difficulty Rating by Crew Position

	TC	GNR	LDR	DRV
Extremely Difficult	1	17	2	3
Fairly Difficult	2	8	4	10
Difficult	3	5	4	3
Somewhat Difficult	12	3	12	10
No Difficulty	15	0	11	6

The respondents were divided 50/50 as to whether the gunner should have a separate escape hatch. The group felt that, considering present tank configurations, a gunner's escape hatch might be a good thing, but they were concerned as to where it could be located.

(1) Driver's hatch. When the respondents were asked if the driver needed an escape hatch, 28 of the 33 respondents answered "Yes." These respondents felt there should be some means for the driver to escape if the tank rolled over. Approximately half of the respondents felt they could escape quickly through the current driver's escape hatch, while the other half felt they could not.

One respondent's comment concerning the driver's hatch is relevant here.

If the main gun is traversed over the driver's hatch, it is impossible for the driver to exit, except through the turret or driver's escape hatch. Also, in some turret positions, it is impossible for the driver to exit through the turret. His access is blocked by the turret's basket design, permitting escape again only through the driver's escape hatch.

(2) Size of hatch openings. Respondents were asked to rate the size of current hatches for each crew position. The rating categories were: (a) the right size, (b) too small, or (c) too large. The majority of the respondents rated the hatches of the M60 series about the right size for all crew positions. The M551 vehicle hatches were rated similarly, with the exception of the loader's hatch, which 10 respondents felt was "too small."

(3) Overall quality of escape systems. The majority of the respondents rated the quality of the escape system on the M60A1 tank as "good" or "very good." Opinions concerning the M551 vehicle were more diverse, with the majority rating it "fair," "good," or "very good." Six respondents rated the M551 escape system as "poor." Seventeen of the respondents had no experience with the M60A2; therefore, ratings on this model were few and varied greatly.

Concerning three-man crews. The current investigation into escape systems was triggered, at least in part, by reports that some tank units in Vietnam employed their tanks in combat with a three-man crew. This configuration dropped the gunner and the tank commander fired the main gun. This arrangement presumably was adopted in realization of the likelihood of the gunner's being trapped by antitank (RPG) fire. Two factors were cited as rendering the gunner's position dangerous: (1)

the inability to quickly escape, and (2) the vulnerability of US tanks to penetration by antitank weapons.

Nineteen respondents reported serving in tank units where three-man crews were a common practice. Seven respondents reported no experience with three-man crews, but all reported knowledge of the practice.

The respondents were asked to list possible reasons for operating with three crewmen. After examining these responses, several good reasons were evident why the gunner was often not employed. A list of the reasons is shown in Table III-3. A number of respondents pointed out that caseless ammunition, as used on the M551, is particularly dangerous to the gunner. Hazards due to explosion of caseless ammunition may be a greater danger than enemy fire alone.

Some of the respondents took exception to the term, "three-man crew." They recounted that, in reality, four men were used but not in the accepted sense. In some instances, a caliber .50 machinegun was mounted to the rear of the turret. The gunner was then positioned on the back deck and was responsible for the security of the left front and left side of the tank. This greatly increased available firepower.

Improving Escape and Evacuation Systems

Comments from respondents indicated that they did not feel technically qualified to make highly specific recommendations for changes in tank design. However, they did provide a number of general suggestions.

Escape systems. The respondents were asked if they felt that the escape system in present tanks could be improved. Approximately half (16) of the respondents felt escape systems could be designed to make it

Table III-3

Reasons For Employing a Three-Man Crew

Tactical and Equipment Considerations

- Due to limited firing ranges, the tank commander was able to aim and fire from the commander's override.
- The mission required mostly area fire, so the tank commander could fire as well as the gunner.
- If hit, the gunner was the most vulnerable crew member.
- The gunner's optics had been removed, so the tank commander had to fire the main gun.
- The gunner was not necessary as most tanks fired anti-personnel, High Explosive (HEP), or cannister ammunition.

Gunner Protection From Enemy Antitank Fire Considerations

- The gunner was usually killed if hit by RPGs.
- At the time there was no tank or antitank threat and we were losing gunners to RPGs and mines.
- The gunner had difficulty in getting out if the tank was hit.
- Tanks attacked by RPGs were usually hit in the vicinity of the gunner.
- The deletion of the gunner eliminated the possibility of his being trapped or killed by concussion from mines.

Personnel Shortages

- Due to a shortage of personnel, this method of operation was usually done only for short periods of time, a day or so at the most.

easier to escape, while 13 felt the present systems could not be improved. Table III-4 is a list of recommendations which the respondents felt would improve the effectiveness of present escape systems.

Evacuation systems. Many of the recommendations made for escape systems also apply to systems intended for the evacuation of wounded or injured personnel, e.g., size of hatch, unobstructed exiting paths, etc. The main concern of the respondents seems to be centered on two major items: (1) increased size of hatches, and (2) provision of rescue straps for aid in moving wounded or injured personnel. Table III-5 lists the recommended improvements for evacuation.

Conclusions and Recommendations

It was apparent from the responses of the group that they felt it was possible to redesign tanks, but as a group they lacked the necessary technical competence to make highly informed recommendations. Tank designs have changed little in recent years, e.g., the crew station locations have remained the same, with few exceptions. As a result, experience with different configurations is limited. However, operator opinions concerning improvements in tank design should be presented to design engineers for consideration.

Interest in improved escape and evacuation systems was evident from the group's responses, and resulted in a list of what appears to be very practical recommendations. These recommendations centered around hatch size and a revised tanker's uniform featuring integral rescue straps.

Table III-4

Recommended Improvements for Escape

Modification to Hatch(es)

- Better designed and fitted driver's escape hatch. (Many are wired on and do not fit right. Some drivers have difficulty in unfreezing the unlocking mechanism.) Change locking mechanism.
- Move driver's hatch so the gun tube does not interfere with the driver being pulled out or in climbing out.
- Fix driver's escape hatch with a safety chain; the loss of the hatch is bad when encountering mines.
- Relocate or redesign driver's escape hatch.
- Design hatches in the sides of the turret, not on top of the turret. This would permit crewmen to exit without having to lift their body weight by their arm strength. It would be less fatiguing and crewmen could exit quicker. German armor vehicles during WWII were usually designed with side doors on the turrets.
- Restructure present hatch openings; make them larger and more oblong to conform to shoulder configurations. If body armor is worn, it makes it difficult to get through hatches.
- Design an escape hatch into the turret wall beside the loader.
- Move driver's hatch away from center position to the side, so the main gun or turret cannot block exiting through the driver's hatch.

Modification of Gunner's Crew Station

- Design a gunner's escape hatch in the tank, possibly on the side of the turret.
- Improve gunner's seat to make it easier to get in and out; either a fold-down or movable gunner's seat.
- Improve egress and exit routes for gunner.
- Redesign gunner's crew station completely.
- Design and locate hand-holds above and behind gunner to aid in getting out.

cont'd

Table III-4 (cont'd)

Modification of Clothing and Personal Equipment

- Better designed tanker's uniform that will not catch on projections. Present field gear hangs when trying to lift oneself through the hatches.
- Recommend that armor crewmen wear less equipment to avoid catching it, e.g., holsters, pistol belts, etc.

Miscellaneous Recommendations

- Eliminate the present commander's cupola (M60 series of tanks) as it hinders escape and evacuation.
- Develop a comprehensive escape training program.
- Add a self-generating smoke screen device or smoke grenade launchers to screen personnel when escaping.
- Design a step (foot- or toe-hold) assist to aid crewmen in getting out.
- Design entry and exit hatches to the turret compartment so crewmen would not have to climb on top of the turret.
- Improve access from the turret to the driver's escape hatch.
- Design self-sealing or self-contained compartments for fuel and ammunition.*
- Improve the "flash point" of the hydraulic fluid so it does not create a fire hazard, or replace it with some other, safer, fluid.
- Examine seating arrangements for all crew members to ensure the most efficient organization and design.

*Authors' note: This is being done on the XM-1.

Table III-5

Recommended Improvements for Evacuation

- Design hatches to conform more to the shape of an individual's shoulders (bigger and more oblong in shape).
- Design tanker's uniform which has built-in rescue straps, like the German uniform. A rescue strap should be mounted on the back at shoulder height.
- Design an evacuation harness which could be attached to a wounded or unconscious crew member to aid in moving and lifting him out of the tank.
- Design a separate tanker harness which is worn by the crewman or design a harness into a tanker's uniform.
- Develop a way to hoist the gunner and driver from their seats.
- Reduce number of sharp projections in the tank. This would reduce injuries and hanging or snagging of clothes and equipment.

SUMMARY AND RECOMMENDATIONS

Training in either escape or evacuation does not appear to have a high priority with the Army. Evidence for this lack of concern is apparent considering the time the respondents served in armor and the very few hours devoted to training in escape or evacuation.

Respondents were slightly taller and tended to weigh more than 1966 averages for armor crewmen. Trends in anthropometric data over the years indicate that our population is getting taller and heavier. If this trend continues, and if armored vehicles continue to provide less internal work space, then crew selection, based on height, weight, and girth, may be the only way to resolve the problem caused by larger crewmen operating in confined spaces.

The majority of the respondents felt their chances of surviving a hit would be less than 50 percent, although they did feel that they could escape quickly through the current tank hatches. Most of them also felt that escape from the gunner's position was the most difficult, followed in difficulty by the driver's position.

Most of the respondents rated the quality of the escape systems on our current tanks as fair to very good. Ratings on the M60A2 were sparse and varied, as few of the respondents had experience with it.

A variety of operational reasons were cited for operating with a three-man crew. These seemed to be the result of sound judgment in view of the tactical situation prevailing in Vietnam.

Followup research on the effects of the hazard posed by caseless ammunition on crew anxiety might prove revealing. There is a possibility that concern with the safety of this ammunition may have affected crews

more than the existing enemy threat. This concern was revealed in conversations with some of the respondents.

The need to examine the various alternatives and develop different escape system concepts was clearly indicated by the respondents. Our current tanks, when combat loaded, greatly restrict and inhibit the quick escape and evacuation of armor crewmen. The best approaches to remedy this situation are not clear at this time, and further study is definitely indicated.

Following are some of the more relevant recommendations gleaned from the responses and comments.

- A realistic and comprehensive training program in escape and evacuation should be developed.
- Training time for both should be substantially increased and made a continuing part of armor training. Training in evacuation of wounded should include some basic emergency medical skills beyond those taught in basic combat training.
- The driver's escape hatch should be better engineered, especially the opening and locking mechanism. Thought should be given to designing the hatch so it can be opened from the outside so personnel can enter the tank to help if it has overturned. An anti-intrusion alert device should be installed on this hatch so the enemy cannot enter the tank during silent-watch and other similar circumstances.
- Exiting the tank under special circumstances such as deep-water fording, or under NBC conditions, should be investigated, as these situations may require changes in the escape system design.
- If possible, the crew stations should be redesigned to provide the gunner with a separate hatch, or at least, to provide the gunner with a more unobstructed route of exiting the tank.
- Tank crewmen should be provided with either separate harnesses or have rescue handles built into a tanker's uniform. Most tankers favor the fabrication of a tanker's uniform with built-in rescue straps, like the German tanker's uniform.

Chapter III

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APPENDIX A TO CHAPTER III

TANK CREW ESCAPE AND EVACUATION QUESTIONNAIRE

APPENDIX A

TANK CREW ESCAPE AND EVACUATION QUESTIONNAIRE

SECTION I

1. Date: _____
(Day) (Month) (Year)
2. Name: _____
(Last) (First) (MI)
3. Rank: _____
4. Age: _____
5. a) Height _____
(Feet) (Inches)
- b) Weight _____
(Pounds)
- c) Size of body frame (use your shirt size)
Small _____
Medium _____
Large _____
Extra Large _____
6. Time in Army: _____
(Years) (Months)
7. Time in Armor: _____
(Years) (Months)
8. Present Military Unit: _____
9. What is your current job title? _____
10. Length of time in your present job: _____
(Years) (Months)
11. What is your present MOS? _____
What is its job title? _____

12. Are you currently serving as a member of a tank crew?

Yes _____

No _____

Check the tank on which you are currently serving, or with which you are most familiar:

M60 or M60A1 _____

M60A1 (AOS) Stabilization _____

M60A2 _____

M60A3 _____

M551 _____

M48A5 _____

Other (Specify the tank model) _____

13. Name each type of tank in which you have crewed and check the name(s) of each crew position you worked in for that tank:

<u>Tank Type</u>	<u>Crew Positions</u>			
_____	TC _____	DRV _____	GNR _____	LDR _____
_____	TC _____	DRV _____	GNR _____	LDR _____
_____	TC _____	DRV _____	GNR _____	LDR _____
_____	TC _____	DRV _____	GNR _____	LDR _____

14. Have you ever served in tanks during combat?

Yes _____

No _____

a) If Yes, indicate where you served in tanks:

Vietnam _____

Korea _____

World War II _____

Other (Please Specify) _____

b) List the tank(s) you served on in combat and name the crew position(s) you held at the time:

1) _____
Tank Crew Position(s)

2) _____
Tank Crew Position(s)

3) _____
Tank Crew Position(s)

4) _____
Tank Crew Position(s)

5) _____
Tank Crew Position(s)

15. Have you received practical training in removing injured personnel from tanks?

Yes _____

No _____

If Yes:

a) When was the training conducted? _____

b) Who conducted the training? _____

c) How many hours of training did you receive? _____

d) How many total hours of training have you received in removing injured personnel since being in armor? _____

e) When was the training conducted? _____
(Year) (Month)

16. Have you received practical training in escaping from a tank?

Yes ☐

No ☐

If Yes:

- a) When was the training conducted? _____
- b) Who conducted the training? _____
- c) How many hours of training did you receive? _____
- d) How many total hours of training in escape have you received since being in armor? _____
- e) When was the training conducted? _____
(Year) (Month)
- f) Have you received training in escaping through the driver's escape hatch?

Yes ☐

No ☐

17. What should be done about the amount of training on escaping from a tank that is given to tank crews? (Check one)

Increase the amount of escape training ☐

Reduce the amount of escape training ☐

Do not change the amount of escape training ☐

18. What should be done about the amount of training given to tank crews on removing injured crewmen from a tank? (Check one)

Increase the amount of training ☐

Reduce the amount of training ☐

Do not change the amount of training ☐

19. a) If your tank was hit and you had to escape from it, what do you feel your chances would be of getting out? (Check one)

No chance at all _____

Wouldn't be too good _____

Would be about average _____

Would be fairly good _____

Would be excellent _____

- b) Estimate your chances of getting out as a percentage:

_____ %

20. For each of the following categories of "hit" on your tank, please estimate the chances of survival (enter it as a percentage) of each crew member:

<u>Hit</u>	Crew Member			
	TC	DRV	GNR	LDR
AP, Hull-Rear	_____ %	_____ %	_____ %	_____ %
AP, Hull-Center	_____ %	_____ %	_____ %	_____ %
AP, Hull-Forward	_____ %	_____ %	_____ %	_____ %
AP, Turret	_____ %	_____ %	_____ %	_____ %
HEAT, Hull-Rear	_____ %	_____ %	_____ %	_____ %
HEAT, Hull-Center	_____ %	_____ %	_____ %	_____ %
HEAT, Hull-Forward	_____ %	_____ %	_____ %	_____ %
HEAT, Turret	_____ %	_____ %	_____ %	_____ %

21. If you had to escape quickly from your tank during an emergency, do you feel that you could get out quickly enough through one of its present tank hatches?

Yes _____

No _____

22. How difficult do you think it is to escape from each of the tank crew positions?

	<u>TC</u>	<u>GNR</u>	<u>LDR</u>	<u>DRV</u>
Extremely difficult	___	___	___	___
Fairly difficult	___	___	___	___
Difficult	___	___	___	___
Somewhat difficult	___	___	___	___
No difficulty	___	___	___	___

23. Should there be an escape hatch especially located for the use of the gunner? (NOTE: On the M60A2 tank the gunner does have his own hatch.)

Yes ___

No ___

24. Should there be a driver's escape hatch on our tanks? (NOTE: This is the hatch in the bottom of the tank.)

Yes ___

No ___

25. Rate the size of the present hatch openings. If you do not know enough about the different tanks or various hatches, place a check in the "No experience" column.

<u>M60/M60A1 Tank</u>				
	<u>TC</u>	<u>LDR</u>	<u>DRV</u>	<u>DRV Escape</u>
The right size	___	___	___	___
Too small	___	___	___	___
Too large	___	___	___	___
No experience	___	___	___	___

M60A2

	<u>TC</u>	<u>GNR</u>	<u>LDR</u>	<u>DRV</u>	<u>DRV Escape</u>
The right size	___	___	___	___	___
Too small	___	___	___	___	___
Too large	___	___	___	___	___
No experience	___	___	___	___	___

M551 Sheridan

	<u>TC</u>	<u>LDR</u>	<u>DRV</u>	<u>DRV Escape</u>
The right size	___	___	___	___
Too small	___	___	___	___
Too large	___	___	___	___
No experience	___	___	___	___

26. Do you feel that you could escape quickly from the tank through the driver's escape hatch in the bottom of the tank?

Yes ___

No ___

27. Have you received training in evacuating wounded personnel by bringing them up through the driver's escape hatch?

Yes ___

No ___

28. Rate the quality of the escape systems of the following types of tanks. If you are not familiar with a particular type, place a check in the "No experience" column.

	<u>M60A1</u>	<u>M60A2</u>	<u>M551</u>
Excellent	___	___	___
Very Good	___	___	___
Good	___	___	___
Fair	___	___	___
Poor	___	___	___
No Experience	___	___	___

29. Which of the following threats to a tanker's survival do you most fear? Enter a #1 beside it and rate as many of the others as you can by entering a "2," "3," "4," etc., beside them. If there are any other items, rank them in the space labeled "Other" and assign them a number.

Trapped by fire ___

Napalm ___

Artillery ___

Aerial bombs or rockets ___

Antitank missiles ___

Enemy tanks ___

Antitank guns ___

Antitank mines ___

Tank ammunition exploding ___

Turning over ___

Other (please specify)

30. During the Vietnam War there were reports that tanks were operated with three-man crews. The gunner was dropped out and the tank commander fired the main gun from the TC's position.

a) Have you ever been in a tank unit where this practice was followed?

Yes ☐

No ☐

b) Have you ever heard any mention of this practice being followed by tank units in Vietnam?

Yes ☐

No ☐

c) If Yes to either of the above two questions, state the reasons you know of for operating with three crewmen:

31. Do you feel that the escape system on your present tank could be improved to make it easier to escape?

Yes ☐

No ☐

If Yes, what improvements would you make?

32. Have you had to escape from a tank during:

Training

Combat

Yes ____

Yes ____

No ____

No ____

33. Have you had to evacuate a wounded or injured crew member from a tank during:

Training

Combat

Yes ____

Yes ____

No ____

No ____

NOTE: If you answered Yes to either question 32 or 33, please complete Section II of this questionnaire.

If you answered No to both questions, turn in Section II to the interviewer.

THIS COMPLETES THE ESCAPE AND EVACUATION QUESTIONNAIRE

SECTION II

PERSONAL EXPERIENCE QUESTIONNAIRE

A. Escape in Combat

1. In what war did you participate? (Check one)

Vietnam _____

Korea _____

World War II _____

Other (Please Specify) _____

2. List the type of tank(s) you escaped from:

3. How many times did you have to escape from your tank? _____

4. Check what crew position(s) you held each time you had to escape:

Tank Commander _____

Gunner _____

Loader _____

Driver _____

5. Through which of the tank hatch(es) did you escape?

Tank Commander ____

Loader ____

Driver (Top) ____

Driver's Escape Hatch ____

6. Check the reason(s) you had to escape:

Tank hit by tank or antitank weapon ____

Tank caught on fire ____

Tank hit a mine ____

Driving accident ____

Other (Please Specify)

B. Escape in Training

1. List the type of tank(s) you escaped from:

2. How many times did you have to escape from your tank? _____

3. Check the crew position(s) you held each time you had to escape:

Tank Commander _____

Gunner _____

Loader _____

Driver _____

4. Through which of the tank hatch(es) did you escape?

Tank Commander _____

Gunner _____

Gunner's Hatch (M60A2) _____

Loader _____

Driver _____

Driver's Escape Hatch _____

5. Check the reason(s) you had to escape:

Tank caught on fire _____

Driving accident _____

Other (Please Specify)

6. What design features would you recommend be added, changed, or eliminated that would make it easier to escape from a tank?

a) Features you would add:

C. Evacuation of Wounded or Injured Crew Members in Combat

1. How many times have you participated in evacuating wounded or injured personnel in combat? _____
2. Check the wounded crew member's position, the hatch through which the crew member was evacuated, and state the cause of the wound or injury each time you performed evacuation:

<u>Crew Position</u>	<u>Hatch</u>	<u>Cause of Wound or Injury</u>
a) TC _____	TC _____	
GNR _____	LDR _____	
LDR _____	DRV _____	
DRV _____	IRV Escape _____	
	GNR (M60A2) _____	
b) TC _____	TC _____	
GNR _____	LDR _____	
LDR _____	DRV _____	
DRV _____	DRV Escape _____	
	GNR (M60A2) _____	
c) TC _____	TC _____	
GNR _____	LDR _____	
LDR _____	DRV _____	
DRV _____	DRV Escape _____	
	GNR (M60A2) _____	

3. What design features would you recommend be added, changed, or eliminated that would make it easier to evacuate wounded or injured personnel?

a) Features you would add

b) Features you would change

c) Features you would eliminate

CHAPTER IV

CLOSED-HATCH TARGET ACQUISITION

Background and Military Problem

It is common knowledge that armor crewmen occasionally experience some form of disorientation to the external environment. The gunner and the loader are the most vulnerable, as they have the least contact with the world outside the tank. This is especially true during movement and/or when the turret is being rapidly traversed from one target location to another. However, all crew members appear to be subject to disorientation when operating in the closed-hatch (buttoned up) mode.¹ This has been attributed, at least in part, to the drastic reduction in the Field of View (FOV) through the vision blocks, and/or the magnification and shallow depth of field of the optical sights. Some studies have suggested that optics with wider FOVs would yield quicker response times in target detection and engagement. These studies further suggested that an ideal system should incorporate a stabilized low power unit for performing surveillance. A higher magnification unit would be employed for detecting concealed targets and recognizing distant targets. The optics should be designed so that the Tank Commander (TC) could shift from one to the other without losing his orientation to the terrain. Current US armored vehicle optics have no such dual capabilities.

¹The material discussed in the remainder of this section has been abstracted from W. L. Warnick, *et al.*, *Study of the Psychophysical and Associated Physiological Effects on a Tank Crew Resulting From Being Buttoned Up*, ARI Research Problem Review 76-13, Human Resources Research Organization, and Army Research Institute, October 1976; from R. C. Barron, *et al.*, *Degradation of Tank Effectiveness*, TCATA Test Report No. FM 325, Final Report (22 September - 24 October 1975), Headquarters, 1RADOC Combined Arms Test Activity, Fort Hood, Texas, 8 September 1976; and from interviews with test officers from the TCATA study.

In attempts to overcome restrictions in the FOV during the TCATA closed-hatch test, some TCs operated with the cupolas rotated 90° or more to the rear. When the cupola is oriented directly to the front, the machinegun mounted on the cupola creates a visual obstruction. Under this condition, the TC must use the unity window of the commander's periscope for frontal vision. Even with the cupola rotated to the rear, it was found that target detection was degraded with the hatches closed. The amount of degradation in target acquisition performance with closed hatches depended on the type of mission. However, degradation was estimated as being from 8 to 25 percent during daylight and from 8 to 46 percent during darkness.

During interviews, commanders also reported that they became disoriented while traversing. This was most frequent following target detection (i.e., original discovery of the presence of a target object) while attempting acquisition (i.e., laying the reticle of the gunsight on the target). This was attributed to blurring of vision or loss of FOV while viewing the surrounding terrain through the vision blocks of the rapidly rotating turret. This disorientation frequently resulted in difficulties in accurately positioning the turret. Consequently, it was necessary for the TC to provide corrective control actions in order to lay on the target. In such cases, time was lost in acquiring the target. As a consequence, some TCs lowered their slew rates (rate of turret traverse) during acquisition to avoid losing sight of the target and thereby achieve a quicker lay. However, the lowered slew rate also tended to increase acquisition times above those observed in the open-hatch mode.

It is virtually certain that US forces will have to operate with closed hatches for considerable periods of time in any future war. Therefore, it seemed appropriate to determine the optimum slew rate in order to minimize degradation of target acquisition performance in the closed-hatch mode. To this end, a small-scale study was planned.

Study I: A Comparison of Tank Commander Target Acquisition Performance While Using Controlled and Uncontrolled Turret Slew Rates

Objective

The primary objective of this study was to compare target acquisition times by the TC under closed- and open-hatch conditions using controlled and uncontrolled turret traversing speeds. A secondary objective was to determine if different cupola positions affected target acquisition times under closed- and open-hatch conditions. In order to keep the research problem within manageable bounds, this study dealt only with target acquisition while the tank and targets were stationary. Furthermore, the targets were easily identifiable and fully exposed so as not to confound target acquisition times with target detection and recognition.

Methods and Procedures

Subjects. Subjects were five TCs from the 1st Cavalry Division, Fort Hood, Texas. Their average experience as a commander was 10 months. Average time in the Army was 4.5 years. The TCs ranged in age from 21 to 29 years. Three of the TCs wore glasses all the time, while the remaining two did not wear glasses.

A larger pool of subjects would have been desirable, but because of other heavy commitments, the Division was only able to provide five TCs.

Test design. At the outset, only hypotheses were available concerning the optimum slew rate. As a result, an arbitrary decision was made to first try a controlled slew rate approximately 25 percent slower than the maximum. Also, two cupola positions were chosen. In the forward position, the TC's frontal view is maximally obstructed. In the rear position, the frontal view is minimally obstructed.

The conditions employed are shown below:

<u>Controlled Rate</u>	<u>Maximum Rate</u>
Cupola forward/closed hatch	Cupola forward/closed hatch
Cupola rear/closed hatch	Cupola rear/closed hatch
	Cupola forward/open hatch

The cupola forward/open hatch condition was included to obtain a baseline against which to evaluate the other conditions. This condition is the one most frequently employed and practiced by TCs.

The order of presentation of the five conditions was randomized and target sequence of presentation was balanced, as best as was possible with the small number of subjects and the limited time they would be available (see Appendix A).

Slew rate control. A device normally employed by turret mechanics to test and adjust the elevating and traversing movements of the TC's control (override) assembly was employed to control slew rate. This device, called a "commander's fixture control," was fabricated locally, according to specifications in a Technical Manual.² The device is

²TM 9-2300-378-35/2. *Direct Support, General Support, and Depot Maintenance Manual for Tank, Combat, Full-Track:* 105-MM Gun, M60A1 W/E (2350-756-8497), Tank, Combat, Full-Track: 105-MM Gun, M60 W/E (2350-678-5773), Tank, Combat, Full-Track: 90-MM Gun, M48A3 W/E (2350-895-9154), Tank, Combat, Full-Track: 90-MM Gun, M48A2C (2350-679-4812), Tank, Combat, Full-Track: 90-MM Gun, M48A2 (2350-346-7560), and Vehicle, Combat Engineer, Full-Track: M728 W/E (2350-726-1297) Gun Elevating and Turret Traversing Systems, HQ, Department of the Army, Washington, D.C., 24 January 1968.

designed with adjustable stops to limit the possible range of movement of the override handle, thus effectively controlling the maximum traverse rate the commander can employ.

Under normal operating conditions the turret is capable of making one complete rotation every 15 seconds. An attempt was made to set the maximum rotation rate at 19 seconds with the fixture control device. However, it was not possible to set the rate with complete accuracy. Therefore, the rates employed actually varied from 18 to 20 seconds.

Test site configuration. Four targets were used. Two targets were large boresighting panels and the remaining two were manmade towers. A panel was also used as a "zero" reference. Target ranges varied from 800 to 1000 meters. The targets were located in a fan or arc in front of the tank. Two targets were located to the right of the zero panel and two targets to the left. The angle between the extreme left target and right hand target was approximately 103 degrees (1823 mils).

The tank was positioned and the main gun aligned on the center of the zero panel and the azimuth indicator was set on 0. The two targets positioned nearest the zero point were located 33 degrees (5910 mils) right and 28 degrees (4971 mils) left of the zero panel. Two additional targets were located 57 degrees (2187 mils) right and 57 degrees (818 mils) left of the zero panel.

The tank was parked on flat open ground with a clear FOV. The terrain was gently rolling with medium height ground cover and patches of dense woods. The target range is shown in Figure IV-1. All targets were large enough to render them extremely conspicuous. See Appendix for order of tank and target conditions.

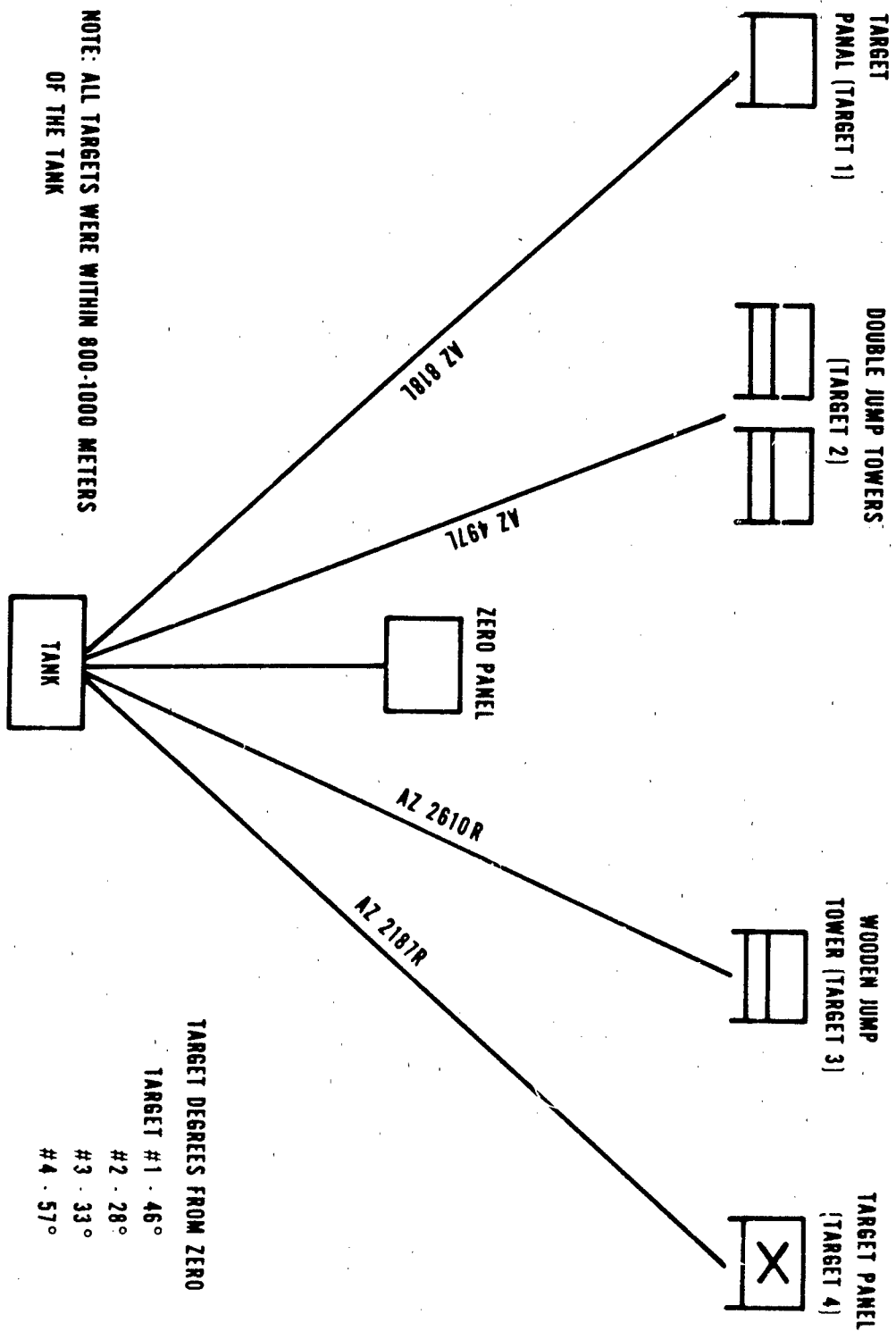


FIG. IV-1. Test site configuration: Study I.

Procedures. The data were gathered over a 3.5 day period. The first day was devoted to the final selection of a tank position, determining the target range, and rehearsing the procedures. The tank position was clearly marked and the tank was repositioned in the same location every day. Ranges and azimuth to targets were also re-verified each day.

The TC of the test vehicle acted as the tank gunner and assisted the experimenter in conducting the target acquisition trials. The TC sat in the gunner's seat and was responsible for verifying that the subject had acquired the correct target and also verified that the subject had laid the main gun reticle in the rangefinder on the approximate center of the targets. The experimenter sat in the loader's seat and timed each acquisition trial using a handheld stopwatch.

Prior to starting, each subject was fully briefed on the purpose of the study and the procedures they were to follow. Any questions were answered at this time. Subjects were instructed to adjust the commander's foot platform and seat to a comfortable position, and also to adjust the rangefinder optics to their own eyes. The turret was then traversed so the subject could positively identify each target, including the zero panel. After the subject verified that he knew the location and identification of each target, he received a number of practice trials to let him get the feel of the power controls. Subjects usually required no more than two or three practice trials before starting their target acquisition trials.

Results

The data obtained were examined by Analysis of Variance (ANOVA) techniques. Table IV-1 presents the ANOVA table comparing the five conditions (i.e., closed hatch/controlled rate/cupola forward, closed/hatch controlled rate/cupola rear, closed hatch/maximum rate of cupola forward, closed hatch/maximum rate/cupola rear, and open hatch/maximum rate/cupola forward). As can be seen, the difference between the conditions is not significant. Therefore, the analysis indicates that there were no reliable differences in acquisition times, regardless of slew rate, cupola position, or position of the hatch.

Table IV-1
Analysis of the Experimental Conditions

<u>Source</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>P</u>
Between Subjects	123.6	4			
Within Subjects	311.2	20			
Conditions	55.1	4	13.8	0.9	NS
Residual	256.1	16	16.0		
TOTAL	434.8	24			

A number of other analyses were also conducted. For example, times to acquire the two inner targets were compared to the times to acquire the outer targets. However, none of these comparisons revealed a significant difference between treatments, so the analysis will not be presented.

Figure IV-2 presents data on learning during the experiment. The mean time shown for Trial 1 is based on the times obtained for each

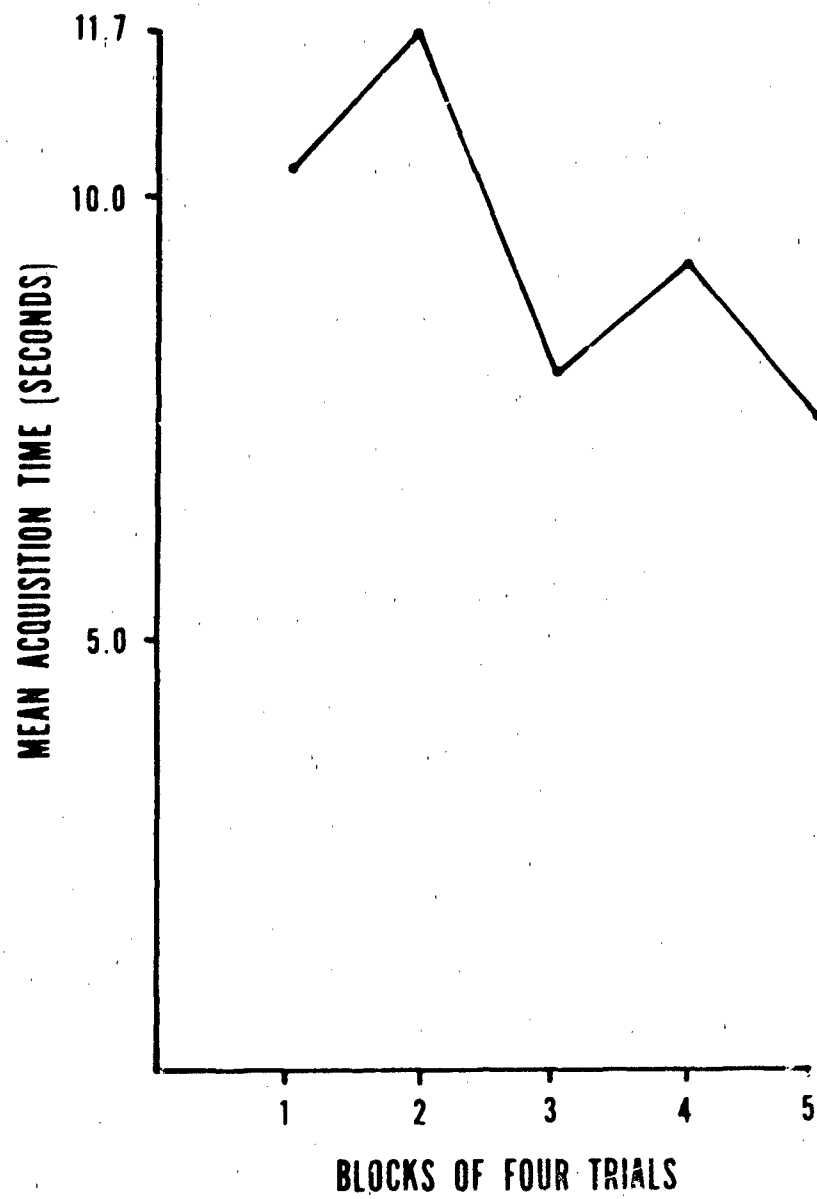


FIG. IV-2. Learning performance for target acquisition trials.

subject during the first series of trials, regardless of condition. That is, each of the five conditions is represented with four trials each. The same is true for Trials 2 through 5. It appears that learning occurred with practice. However, an ANOVA comparing the first two series with the last two series did not result in a significant F ratio. Therefore, it cannot be concluded that the observed trend is reliable.

Conclusions

Although no significant results were obtained in the preliminary study, it served to generate several hypotheses for a second study. First of all, it was hypothesized that more practice in using the turret control would lead to greater stability in the results. This hypothesis was partly based on the data shown in Figure IV-2, and partly on post-test interviews with the subjects. The subjects reported that they were "just getting organized" in their techniques for acquiring targets when their participation was concluded. Therefore, it was hypothesized that differences between the experimental conditions might have emerged if participants had been allowed to reach their peak in performance in each condition prior to testing.

A second hypothesis concerned the use of an "aiming reference." Subjects reported that they had learned to use a reference point in slewing to a target with the hatch closed. It is virtually universal in the open-hatch mode to use the main gun barrel as a reference. However, with hatches closed, they chose some other aiming reference such as a nut or bolt on the outside of the turret to help them align the turret

with the target. This was because when the hatch is closed, it is difficult to judge the actual alignment of the gun barrel with the target. Therefore, it was hypothesized that an easy-to-use aiming reference would aid in acquiring targets in the closed-hatch mode.

The TCs also reported no disorientation when traversing the turret at the maximum rate. They felt that the use of an aiming reference provided quicker target acquisition. They also felt that the disorientation reported during the TCATA test was due to lack of practice in the closed-hatch mode. Therefore, it was tentatively concluded that slowing the traverse rate was not necessary.

Based on these hypotheses, a second study was planned for a time when both personnel and an operable M60A1 tank would be available for a longer series of trials. This study is described in the next section.

Study II: Use of an Aiming Reference by the Tank Commander in Target Acquisition in the Closed-Hatch Mode

Background and Military Problem

The design of this second study was based on:

1. The indications that TCs in Study I needed more practice in target acquisition to prevent performance times from being confounded by learning effects.
2. Indications from Study I that slowing the slew rate was not necessary.
3. Personal observations and TC comments during Study I on the use of some internal reference mark within the cupola or an external reference mark on the outside surface of the tank as an aid in aligning the turret and main gun onto a target.

The reference system used varied among TCs, but was usually a "nut" or a sharp projection. However, any easily recognizable feature could serve as a usable sighting reference. The TC would traverse the turret towards the target and then visually align the reference mark on the target. This ensured that the gun tube was aligned closely in azimuth to the target or target area. Then the TC would look through his range-finder, and either elevate or depress the main gun until on target. The use of the aiming reference was believed by the TCs to reduce the number and degree of small horizontal tracking movements (jockeying) required to align the main gun on the target in azimuth.

The notion behind an aiming reference is not new. Many years ago, tanks were equipped with "vane" sights. This was a metal projection welded to the top of the turret in front of the commander's hatch. The vane sight was used by commanders to initially lay the main gun in the vicinity of the target. The use of the vane sight supposedly reduced search time for the gunner and allowed him more time to make a "fine" lay on the target. The vane sight is no longer incorporated on our current tanks. The M46 tank, which was used in Korea, is believed to be the last tank with a vane sight. The reasons for eliminating the vane sight are not known. The TCs felt that an adaptation of this concept would be helpful while firing in the closed-hatch mode.

Objective

The primary objective of this study was to determine, under closed-hatch conditions if the use of an aiming reference system would improve target acquisition times. Two ancillary objectives were: (1) to determine more precisely how many acquisition learning trials are required to

stabilize performance, and (2) to determine if cupola position affects target acquisition performance.

In order to keep the research problem within manageable bounds, this study dealt only with target acquisition while the tank and targets were stationary. Furthermore, the targets were easily identifiable and fully exposed so as not to confound target acquisition times with target detection and recognition.

Methods and Procedures

Subjects. Seven TCs from the 1st Cavalry Division, Fort Hood, served as subjects. One was an E6, five were E5s, and one was an E4. Average experience as a TC was approximately five months. All were serving as TCs at the time this investigation was conducted.

A larger number of subjects would have been desirable, but because of other heavy commitments, the Division was able to provide only seven.

Test design. Table IV-2 depicts the test conditions that were used. Each subject completed 60 target acquisition trials with and 60 without the aiming reference for a total of 120 trials over the entire study. Under each aiming reference condition, the subjects completed 48 training trials followed by 12 test trials. A trial is defined as the time taken to slew the turret from the zero point and place the cross-hair of the rangefinder on the approximate center of mass of the appropriate target. Two different sets of four targets each were employed for training and testing. This was done to ensure that the subjects had learned general procedures or techniques rather than simply learning how best to acquire one specific set of targets. The test set

Table IV-2
Test Conditions

Without Aiming Reference

Training Targets

Cupola forward/closed hatch
(16 trials)

Cupola rear/closed hatch
(16 trials)

Cupola forward/open hatch
(16 trials)

TOTAL 48 trials

Test Targets

Cupola forward/closed hatch
(4 trials)

Cupola rear/closed hatch
(4 trials)

Cupola forward/open hatch
(4 trials)

TOTAL 12 trials

With Aiming Reference

Training Targets

Cupola forward/closed hatch
(16 trials)

Cupola rear/closed hatch
(16 trials)

Cupola forward/open hatch
(16 trials)

TOTAL 48 trials

Test Targets

Cupola forward/closed hatch
(4 trials)

Cupola rear/closed hatch
(4 trials)

Cupola forward/open hatch
(4 trials)

TOTAL 12 trials

of targets was selected to approximate the training set in terms of angles and ranges. Insofar as possible the order of presentation of both conditions and targets was counterbalanced across subject (see Appendix B).

Aiming reference. The aiming reference consisted of two 1/8 inch wide strips of adhesive tape. One of these was attached vertically to the outside of the viewing window, bisecting it. The TC then laid the crosshair in the rangefinder on the center of one of the targets. Following this, he placed the second strip of tape on the inside of the window so the inner and outer strips were aligned with the target. Finally, he assumed his normal operating position and checked that, when coincident, the two marks bisected the target. If not, the inner strip was adjusted. The TCs found that alignment was easier if only one eye was used. They also reported using only one eye when actually acquiring targets with the aid of the aiming reference. The aiming reference was attached to the unity window of the commander's sight when the cupola was in the forward position, and to the center vision block when the cupola was in the rear position.

Test site configuration. The test site was configured much the same as in Study I. However, two sets of four targets (one for training and one for testing) were employed. The test vehicle was placed on a small hill which overlooked the surrounding area. All targets were either manmade or easily identifiable natural terrain features. The layout of the target arrays is shown in Figure IV-3.

Procedures. The procedures employed were essentially the same as those used in Study I. Commanders were first briefed on the target locations. Upon entering the tank, each TC was told to adjust the seat,

TARGET ARRAYS TRAINING TARGETS

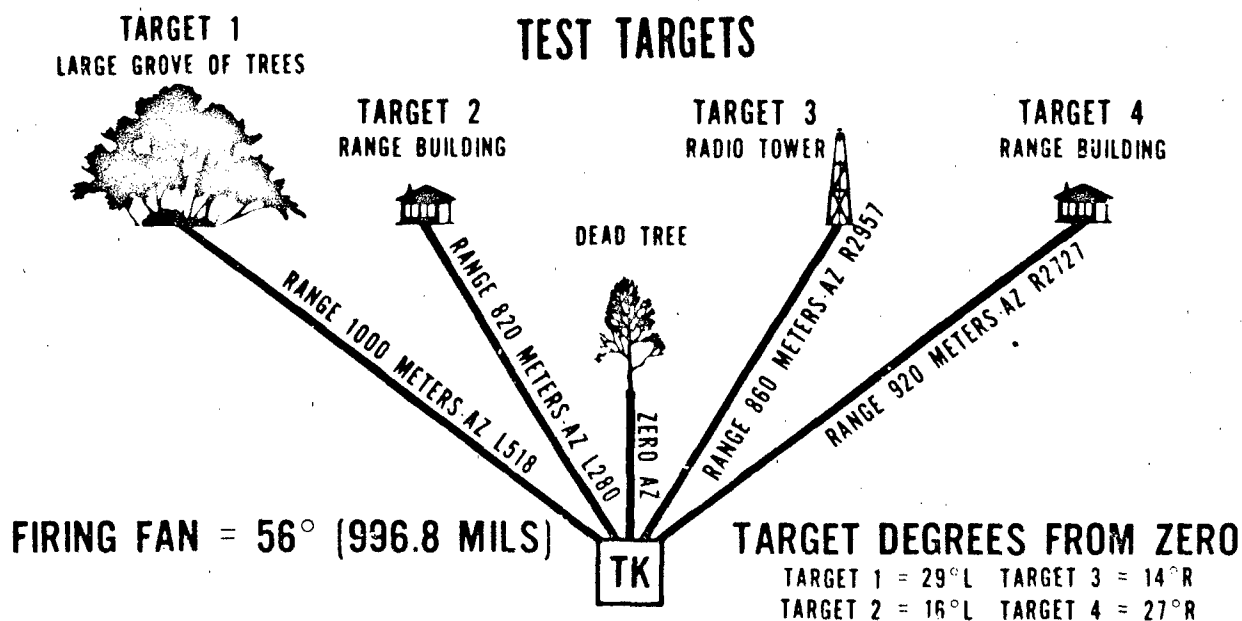
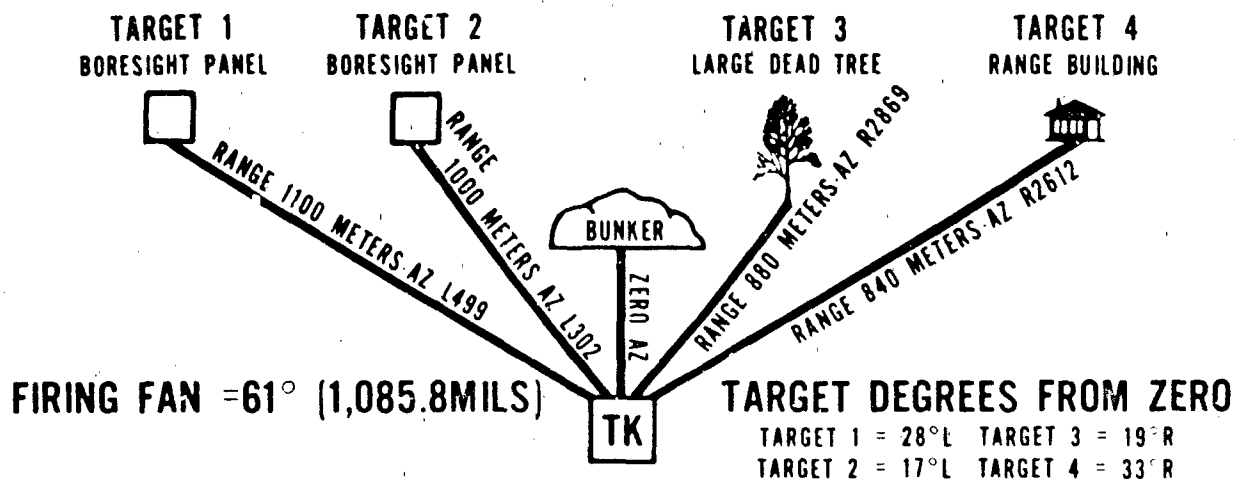


FIG IV-3. Test site configuration. Study II.

foot platform, rangefinder distance settings, etc., and make any other adjustments he would normally make in his own tank. The military assistant, seated in the gunner's seat, then moved the turret and aligned the gunner's sight on the zero panel. The commander verified that the gun laying reticle in the rangefinder coincided with the gunner's aiming point. The experimenter verified the reticle settings. The assistant then traversed the turret and laid on each of the four "training" targets.

The TC was then instructed to traverse the turret and lay on each target with the hatch open and then with the hatch closed. Each TC was given the chance to observe and practice laying on all targets to minimize misidentification. This procedure was followed each time the cupola position was changed. The same procedure was followed for the "test" targets.

During both training and testing, commanders were told to align their sighting reticle as near center of mass as possible for each target or target area. The military assistant, who was a tank commander, verified that each commander had laid on the correct target and was aligned on the approximate center of target mass.

Targets for each trial were designated by the experimenter who called a number which designated each target.

Two subjects were run per day -- one in the morning and one in the afternoon. Each TC took approximately two hours to finish the 120 target acquisition trials, including practice and installation or removal of the aiming reference. Timing was accomplished by the use of a handheld stopwatch. The time for each trial was rounded to the nearest whole second.

Results

Table IV-3 gives the means and standard deviations for all of the test conditions and all of the targets. Inspection of the tabled values will reveal a remarkable similarity between the mean acquisition times for all of the conditions. The range is only from 5.5 seconds to 7.0 seconds. The standard deviations for these means show a similar lack of variability between conditions.

Appendix C graphically presents acquisition times for the various targets with and without an aiming reference. The reader is directed to these figures if he/she has any special interest, but it should be noted that the actual differences between the bars is very small.

Appendix D shows the frequency distribution of times, both with and without the aiming reference. These distributions are mainly noteworthy for their negative skewness. This is typical of latency type measures.

Figure IV-4 displays learning curves for various conditions over four blocks of trials. Each curve presents the composite performance of the seven subjects. It is interesting to note that in the majority of the conditions, performance continues to improve with practice, even over 112 trials. This indicates that the task of accurately controlling turret movement is very difficult and that considerable practice would be required before a plateau in learning would be reached. This difficulty in learning is most likely due to the considerable lag and non-linearity between control movement and system response.

Analysis of variance. The data from the study were then subjected to an Analysis of Variance (ANOVA). The design of the study permitted the use of a five-factor factorial ANOVA (aiming reference x training

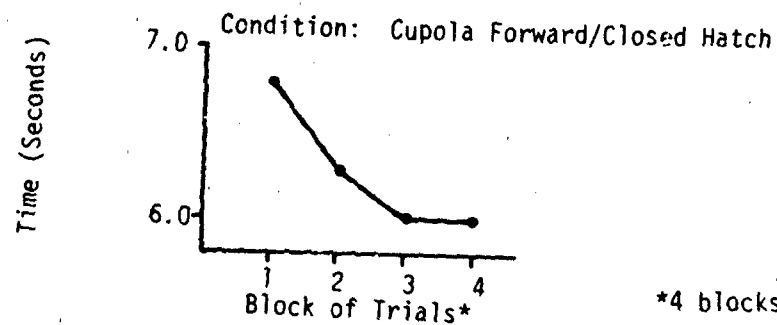
TABLE IV-3

Acquisition Times in Seconds for All Conditions and Targets

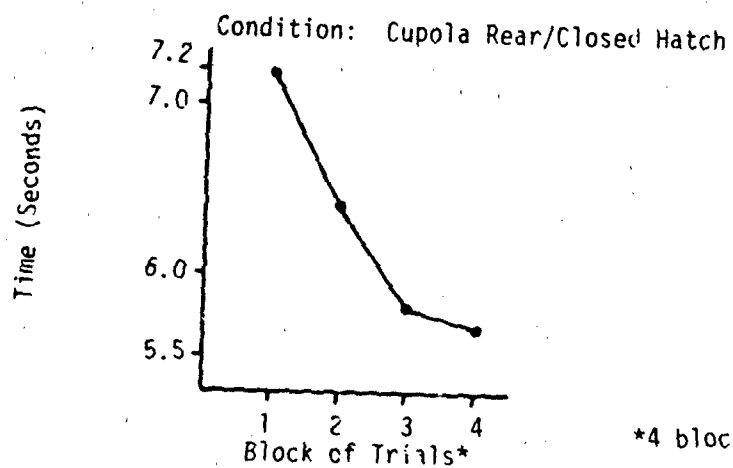
<u>Conditions</u>	<u>N</u>	<u>\bar{x}</u>	<u>SD</u>
All conditions with and without aiming reference	840	6.1	2.19
All conditions with aiming reference	420	6.2	2.48
All conditions without aiming reference	420	6.1	1.87
Training & test with aiming reference			
Cupola forward/closed hatch	140	6.5	1.64
Cupola rear/closed hatch	140	5.5	3.46
Cupola forward/open hatch	140	6.5	1.76
Training & test without aiming reference			
Cupola forward/closed hatch	140	6.3	2.09
Cupola rear/closed hatch	140	5.5	1.51
Cupola forward/open hatch	140	6.4	1.82
With aiming reference (training targets)			
Cupola forward/closed hatch	112	6.3	1.18
Cupola rear/closed hatch	112	6.3	2.00
Cupola forward/open hatch	112	6.6	1.87
With aiming reference (test targets)			
Cupola forward/closed hatch	28	7.4	2.70
Cupola rear/closed hatch	28	6.0	1.41
Cupola forward/open hatch	28	6.1	1.41
Without aiming reference (training targets)			
Cupola forward/closed hatch	112	6.3	2.09
Cupola rear/closed hatch	112	5.5	1.51
Cupola forward/open hatch	112	6.4	1.82
Without aiming reference (test targets)			
Cupola forward/closed hatch	28	6.1	2.19
Cupola rear/closed hatch	28	5.7	1.94
Cupola forward/open hatch	28	6.6	1.51

NOTE: Each subject performed a total of 120 target acquisition engagements; thus, each mean is based on measurements of acquisition time.

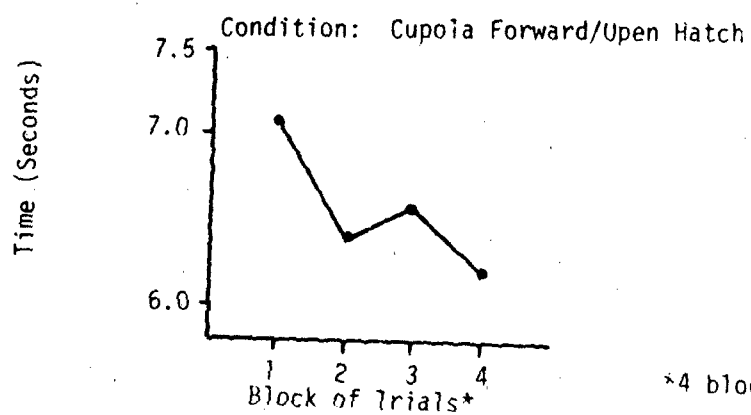
Training Targets
With Aiming Reference



*4 blocks of 28 trials per block



*4 blocks of 28 trials per block



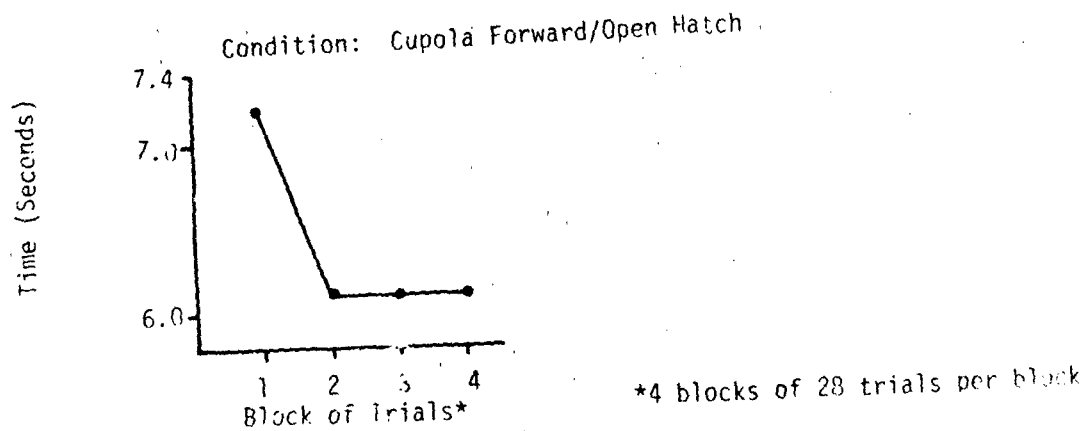
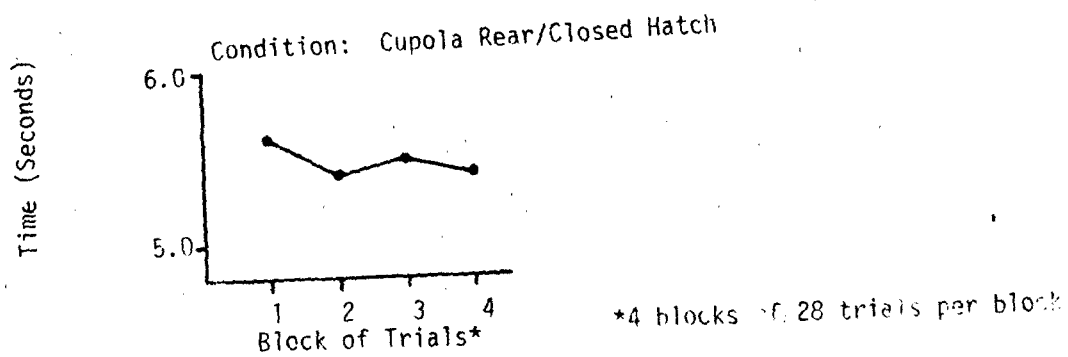
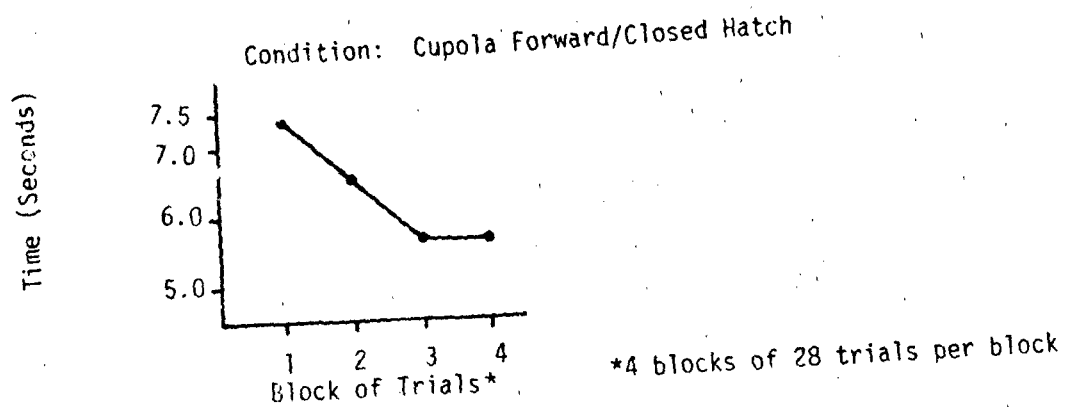
*4 blocks of 28 trials per block

FIG. IV-4. Mean time to lay on target

(cont'd)

FIG. IV-4 (cont'd)

Training Targets
Without Aiming Reference



condition x cupola position x target x subjects). Trials were not included as an experimental factor because different numbers of trials were performed under training and test conditions. Each subject received a score for each treatment condition that was a mean of the trials he had received under that condition. This is a particularly powerful form of ANOVA which, however, is very cumbersome to compute. The analysis allows testing of all main effects and all interactions and, as it is generally computed, offers a separate error term for each comparison. However, for the present case, it was decided not to present any of the interactions of a higher order than the three-way. This decision was based on the observation that the four-way interaction was not significant, and of little experimental interest. Therefore, the four-way interaction was pooled with the error terms for all other factors and interactions, yielding a single error term with 294 degrees of freedom.

The results of the ANOVA are presented as Table IV-4. A brief survey of the tabled F values will reveal that none of them approaches significance. Thus, the null hypothesis of no difference between the experimental conditions cannot be rejected.

CONCLUSIONS

Although this investigation was concerned only with the acquisition of stationary targets from a stationary tank, the results are quite heartening. No degradation was observed in target acquisition performance in the closed-hatch mode. Furthermore, the modal time of five seconds indicates that a first round could usually be fired within six or seven seconds, even in the closed-hatch mode. This result was sur-

Table IV-4

Analysis of Variance Results

<u>Factor</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>P</u>
A	10.1	1	10.1	.22	-
TT	0.7	1	0.7	.02	-
Cp	27.6	2	13.8	.30	-
T	14.7	3	4.9	.11	-
Ss	368.8	6	60.6		
A x TT	0.1	1	0.1	.00	-
A x Cp	9.2	2	4.6	.10	-
A x T	4.7	3	1.6	.03	-
TT x Cp	5.6	2	2.8	.06	-
TT x T	3.7	3	1.2	.03	-
Cp x T	13.0	6	2.2	.05	-
A x TT x Cp	31.2	2	15.6	.34	-
A x Cp x T	32.4	3	10.8	.23	-
TT x Cp x T	36.6	6	6.1	.13	-
Error	<u>13,580.6</u>	<u>294.0</u>	46.2		
TOTAL	14,135.0	335.0			

A = With and without aiming reference
 TT = Training and test conditions
 Cp = Cupola positions
 T = Individual targets
 Ss = Subjects

prising, as TCATA reported mean detection-to-engagement times ranging from 9.6 to 18.8 seconds. The task in the present research was somewhat simpler than that faced by the TCATA test participants. However, the times obtained in the present study were considerably lower than expected based on the previous work.

Chapter IV

LIST OF REFERENCES CITED

(All references are unclassified.)

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- Warnick, W. L., Kubala, A. L., Maxey, J. L., and Ton, W. H. *Study of the Psychological (and Associated Physiological) Effects on a Tank Crew Resulting From Being Buttoned Up*, ARI Research Problem Review 76-13, Human Resources Research Organization, and Army Research Institute, October 1976.

APPENDIXES TO CHAPTER IV

APPENDIX A
TEST SCHEDULE

Order of Test Conditions

- I. Open Hatch Acquisition: No Speed Control, Cupola Forward
- II. Closed Hatch Acquisition: Controlled Speed, Cupola Forward
- III. Closed Hatch Acquisition: No Speed Control, Cupola Forward
- IV. Closed Hatch Acquisition: No Speed Control, Cupola Rear
- V. Closed Hatch Acquisition: Controlled Speed, Cupola Rear

Order of Tank Acquisition Conditions Among Subjects

<u>1st Day</u>	<u>2nd Day</u>	<u>3rd Day</u>
I	II	III
II	III	I
III	I	II
IV	V	IV
V	IV	V

Target Trials

Each subject acquired four different targets under each condition. The target acquisition sequence was randomized among the four targets for each subject.

APPENDIX B

TANK ACQUISITION CONDITIONS

Training Targets

- | | |
|--|---|
| <p>A. W/O Aiming Reference</p> <ol style="list-style-type: none"> 1. Cupola forward/closed hatch 2. Cupola rear/closed hatch 3. Cupola forward/open hatch | <p>B. W/ Aiming Reference</p> <ol style="list-style-type: none"> 1. Cupola forward/closed hatch 2. Cupola rear/closed hatch 3. Cupola forward/open hatch |
|--|---|

Test Targets

- | | |
|--|---|
| <p>c. W/O Aiming Reference</p> <ol style="list-style-type: none"> 1. Cupola forward/closed hatch 2. Cupola rear/closed hatch 3. Cupola forward/open hatch | <p>D. W/ Aiming Reference</p> <ol style="list-style-type: none"> 1. Cupola forward/closed hatch 2. Cupola rear/closed hatch 3. Cupola forward/open hatch |
|--|---|

Order of Tank Acquisition Conditions Among Subjects

	<u>S-1</u>	<u>S-2</u>	<u>S-3</u>	<u>S-4</u>	<u>S-5</u>	<u>S-6</u>	<u>S-7</u>
<u>TNG</u>	A1	B1	B2	A2	A1	B1	B2
	A2	B2	B1	A1	A2	B2	B1
	A3	B3	B3	A3	A3	B3	B3
<u>TEST</u>	C1	D1	D1	C1	C1	D1	B1
	C2	D2	D2	C2	C2	D2	D2
	C3	D3	D3	C3	C3	D3	D3
<u>TNG</u>	B1	A2	A1	B1	B2	A2	A1
	B2	A1	A2	B2	B1	A1	A2
	B3	A3	A3	B3	B3	A3	A3
<u>TEST</u>	D1	C1	C1	D1	D1	C1	C1
	D2	C2	C2	D2	D2	C2	C2
	D3	C3	C3	D3	D3	C3	C3

Target Trials

Target acquisition sequence was balanced across each of the two sets of targets used. Each set consisted of four targets. Below are examples from original scores sheets:

Condition: Gun Forward/Closed Hatch

<u>Trial</u>	<u>Target</u>	<u>Target</u>	<u>Target</u>	<u>Target</u>
1	4	1	2	3
2	3	2	1	4
3	1	3	4	2
4	2	4	3	1

Condition: Gun Rear/Closed Hatch

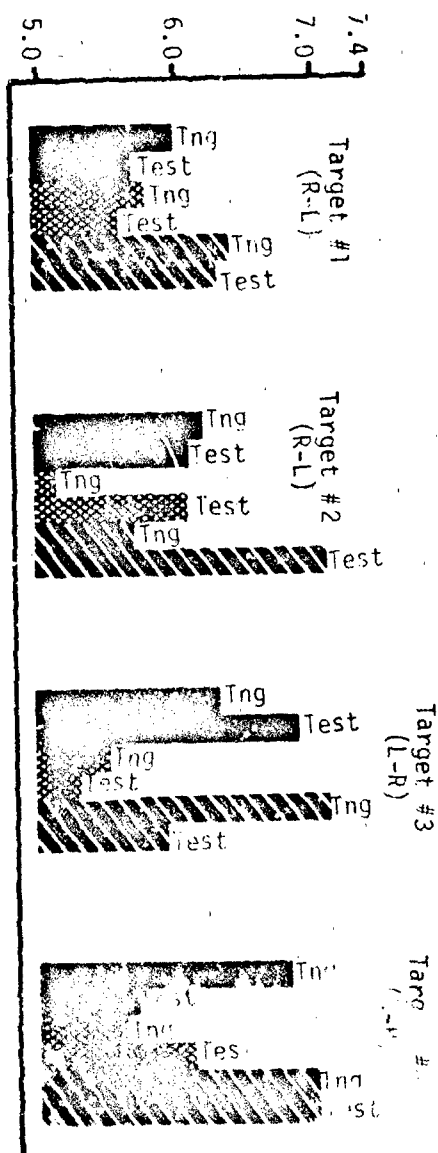
<u>Trial</u>	<u>Target</u>	<u>Target</u>	<u>Target</u>	<u>Target</u>
1	3	2	1	4
2	1	3	4	2
3	2	4	3	1
4	4	1	2	3

APPENDIX C TO CHAPTER IV

TARGET ACQUISITION TIMES WITH AND WITHOUT AIMING REFERENCE

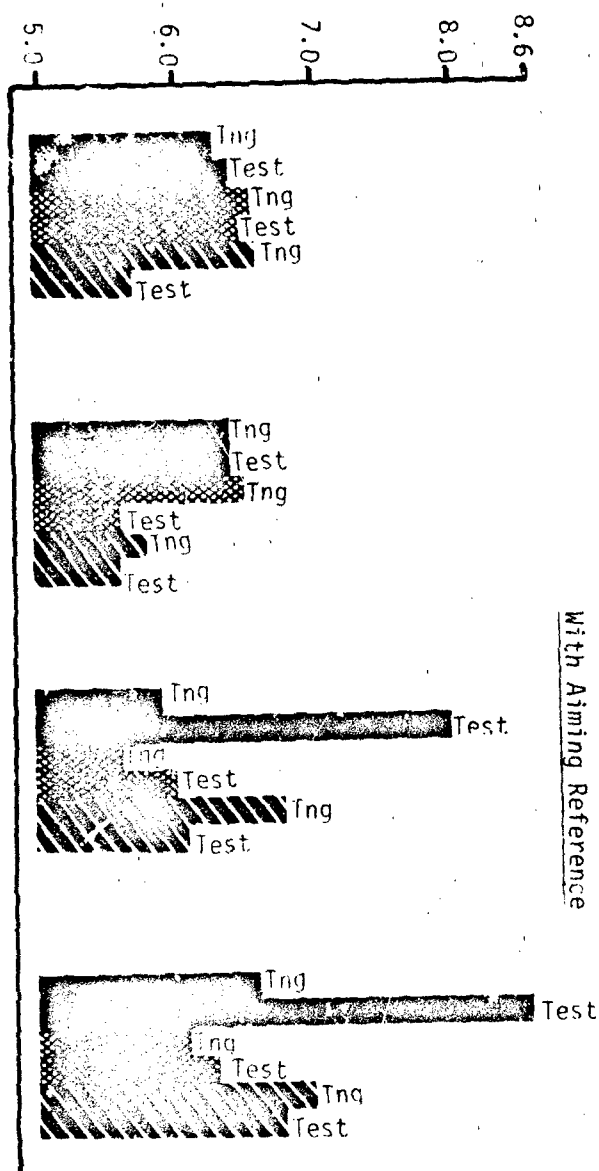
Performance Times: Training vs Test

Without Aiming Reference



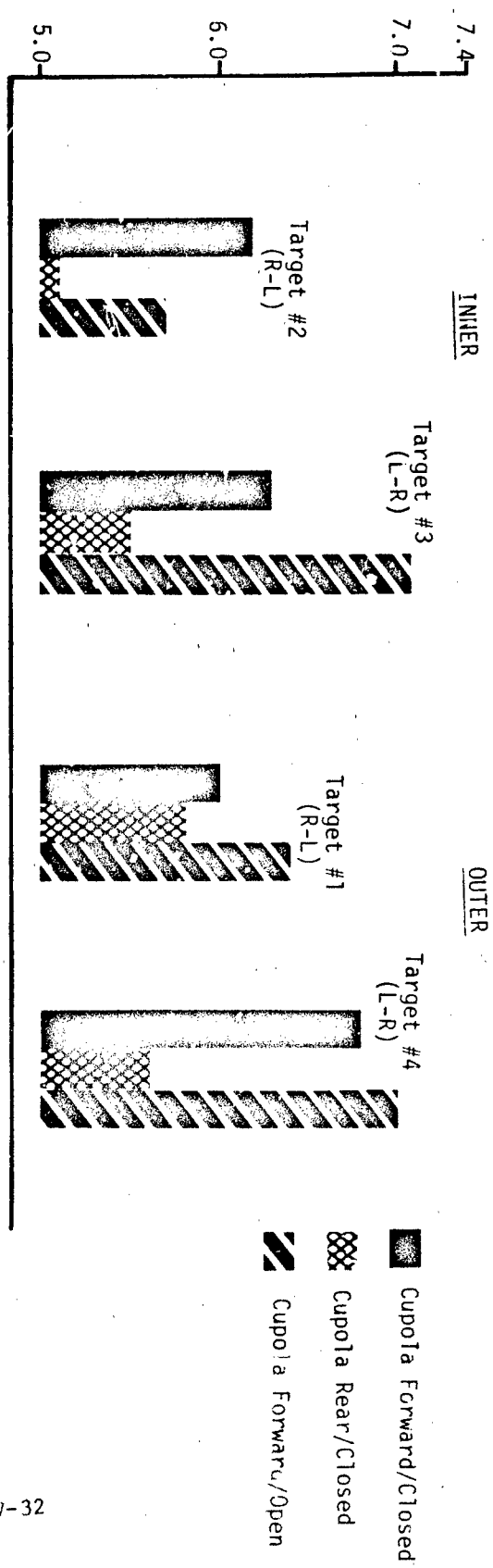
- Cupola Forward/Closed
- ▨ Cupola Rear/Closed
- ▧ Cupola Forward/Open

With Aiming Reference

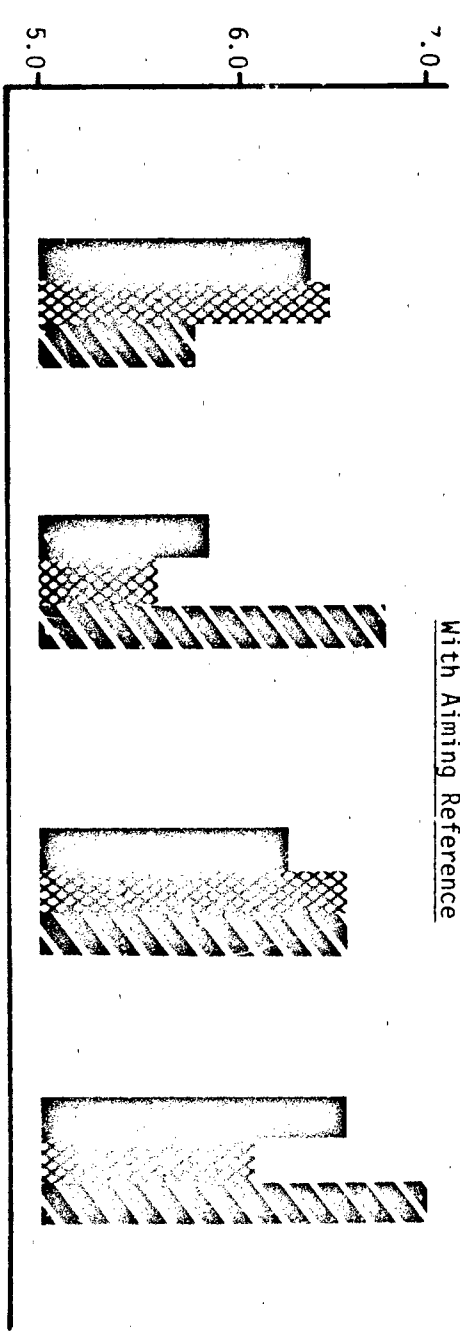


Performance Times: Inner vs Outer Targets
Training Targets

Without Aiming Reference



With Aiming Reference



Performance Times: Inner vs Outer Targets
Test Targets

Without Aiming Reference

INNER




OUTER

Target #2
(R-L)

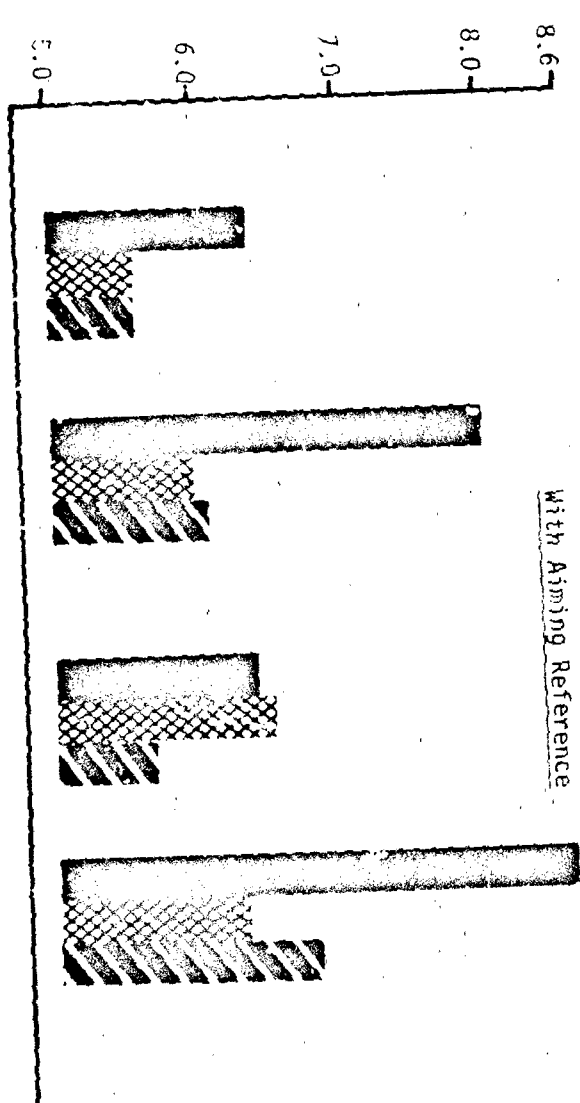
Target #3
(L-R)

Target #1
(R-L)

Target #4
(L-R)

-  Cupola Forward/Closed
-  Cupola Rear/Closed
-  Cupola Forward/Open

With Aiming Reference



APPENDIX D
DISTRIBUTION OF TARGET ACQUISITION TIMES

<u>Time (Seconds)</u>	<u>No. Responses W/ Aiming Reference</u>	<u>No. Responses W/O Aiming Reference</u>	<u>Combined Totals</u>
17	-	1	1
16	1	1	2
15	1	1	2
14	1	1	2
13	3	3	6
12	2	-	2
11	2	5	7
10	13	7	20
9	23	10	33
8	36	32	68
7	84	73	157
6	<u>113*</u>	93	206
5	104	<u>134*</u>	<u>238*</u>
4	15	52	87
3	2	5	7
2	-	2	2
	N = 420	N = 420	N = 840

*Modal score for each category.

CHAPTER V

TANK CREW MEASURES OF EFFECTIVENESS

Military Need

In case of hostilities in central Europe, friendly forces are expected to be greatly outnumbered. In order to survive and win in such circumstances, they must be the best trained and most effective fighting force in the world. In order to ensure maximum effectiveness of US forces, Measures of Effectiveness (MOE) for all aspects of armored operations must be derived so that commanders can evaluate their own crews, discover deficiencies, and take corrective measures.

MOE can be classified for purposes of discussion into those concerned primarily with military hardware, and those concerned primarily with the personnel who operate the hardware. MOE for military hardware are generally explicit, quantitative, and specified prior to development in the Required Operational Capabilities (ROC) document. Firing rates, effective ranges, maximum march order and emplacement times, mean circular miss distances, and single shot kill probabilities against particular targets are frequently employed examples. Tests to determine whether an item of hardware meets such objectives are conducted under carefully controlled conditions, with every effort being made to ensure proper maintenance and operation of the system. However, determining the efficiency or capability of the hardware is not the purpose of this research. Our objective is determining the efficiency and capability of the crew in making maximum use of the system as *it is*. The ultimate goal of this research is to derive M² to determine exactly how well crews are meeting that objective.

Effectiveness, or potential effectiveness, of operator personnel is typically determined by the employment of job proficiency tests. Harris, et al.,¹ identified five areas in which job proficiency tests played an important role in decision making. These are:

1. Evaluating training
2. Evaluating MOS proficiency
3. Evaluating changes to the personnel system
4. Conducting personnel research
5. Determining unit readiness.

The primary focus of this effort, as implied by the title, "Tank Crew Measures of Effectiveness," is on the fifth area cited by Harris and his co-workers. However, it must be pointed out that MOE must do much more than simply indicate a readiness status. To be maximally useful, these measures must also provide diagnostic information. That is, they must tell us exactly where any deficiencies in performance occur. Without such information, corrective steps cannot be taken, and the ultimate goal of most evaluation is the elimination of deficiencies or shortcomings. Therefore, when evaluating readiness, one is also evaluating training, and developing information to feed back to training managers.

In stating that an individual, a crew, or a larger personnel unit is "effective," we typically imply that some predetermined standard has been met. For example, we might provide a standard such as the following:

¹J. H. Harris, R. C. Campbell, W. C. Osborn, and J. A. Boldovici. *Development of a Model Job Performance Test For a Combat Occupational Specialty, Volume I. Test Development; Volume II: Instructions and Procedures for Conducting a Functionally Integrated Performance Test*, Final Report FR-CD(L)-75-6, Human Resources Research Organization, Alexandria, Virginia, November 1975.

Given (a) a stationary M60A1AOS tank with the main gun battlesighted with SABOT, (b) an operational gunner's day periscope, and (c) a moving tank target that is visible at less than 3200 meters without artificial light during the day; gunner will open fire within 16 seconds, and neutralize the target within 24 seconds of the alert element of the tank commander's command, using no more than two rounds.²

If the gunner meets this performance standard, he is rated an effective gunner. If not, he is deemed ineffective, and is typically given refresher training. However, scoring is typically on a "GO" or "NO-GO" basis. Gunners may receive extra credit points for exceeding the standard by some given amount, but those who fail to meet the standard are simply considered failures. In other words, the standard represents the minimum acceptable level of performance.

Against this background, it would seem that to develop tank crew MOE, it would only be necessary to determine what tank crews do, and develop minimal acceptable standards of performance. In concept, this seems simple enough. However, as will be seen in the following sections, the problems involved in deriving MOE are both numerous and difficult.

Background and Approach

At the outset, three objectives were set for this phase of the research on tank crew MOE. These were:

- a. To determine what set of MOE were currently being employed by commanders, and to assess their reliability and validity for combat.

²R. E. Kraemer, J. A. Boldovici, and G. G. Boycan. *Job Objectives For M60A1AOS Tank Gunnery*, Research Memorandum 76-9, Human Resources Research Organization, and Army Research Institute, April 1976.

- b. To determine what critical functions were not currently being evaluated.
- c. To propose a research program to develop the necessary information to derive MOE for those critical functions not being currently evaluated.

These objectives were to be met by first surveying all of the ongoing and previous work in the area to determine what gaps needed to be filled. Therefore, as a first step, an attempt was made to locate literature dealing with MOE, and to discover what other military agencies were conducting relevant work. Early during this step it became apparent that techniques for evaluating the performance of crews or larger personnel units were still in their infancy. Wagner, et al.,³ summarized the state-of-the-art in team training and evaluation strategies. While this work was not specifically directed toward tank crews, a tank crew is encompassed within the authors' meaning of the term "team." Borrowing heavily on the definition of a team presented by Glaser, Klaus, and Egerman,⁴ Wagner and his co-workers define team training as:

The training of two or more individuals who are associated together in work or activity. The team is relatively rigid in structure and communication pattern. It is goal or mission-oriented with the task of each team member well-defined. The functioning of the team depends upon the coordinated participation of all or several individuals. The focus of team training and feedback is on team skills (e.g., coordination), activities and products.

³H. Wagner, N. Hibbits, R. D. Rosenblatt, and R. Schulz. *Team Training and Evaluation Strategies: State-of-the-Art*, Technical Report 77-1, Human Resources Research Organization, Alexandria, Virginia, February 1977.

⁴R. Glaser, D. J. Klaus, and K. Egerman. *Increasing Team Proficiency Through Team Training: 2. The Acquisition and Extinction of a Team Response*, Technical Report AIR B64-5/62, American Institutes for Research, May 1962.

This report points out, that while the military services conduct up to 90 percent of their training in the operational commands, most training research has been focused on individual training in institutional settings. For example, in FY 1974, the Army Research Institute (ARI) conducted the largest program of unit training and evaluation research in history. Yet, less than two million dollars (only 11 percent of the human resources research budget) was spent in this area, although sporadic work was conducted over the previous 20 years. Therefore, many gaps were found to exist in state-of-the-art team training strategies and evaluation techniques.

Although Wagner, *et al.*⁵ reported that work specific to team training and evaluation was comparatively sparse, the present authors found a considerable body of literature dealing with MOE in general, and some dealing specifically with training effectiveness and operational effectiveness. For example, TRADOC PAM 11-8,⁶ *Cost and Operational Effectiveness Analysis Handbook*, and TRADOC PAM 71-10,⁷ *Cost and Training Effectiveness Analysis Handbook*, obviously deal with the concepts of operational and training effectiveness. However, upon closer examination these two publications are of only marginal value for the present research. TRADOC PAM 11-8 is oriented toward an evaluation of the

⁵Wagner, *et al.*, *op. cit.*

⁶TRADOC PAM 11-8. *Cost and Operational Effectiveness Analysis Handbook*, US Army Training and Doctrine Command, Fort Monroe, Virginia, November 1974.

⁷TRADOC PAM 71-10. *Cost and Training Effectiveness Analysis Handbook* (Draft), US Army Training and Doctrine Command, Fort Monroe, Virginia, November 1976.

operational effectiveness of new materiel, different organizational concepts, and different operational concepts. The techniques described for assessing effectiveness do not seem to be applicable to assessing the performance of personnel. In fact, PAM 11-8 provides virtually no advice on the selection of MOE. Its authors assume that the MOE will be provided by an agency other than the one actually conducting the analysis. The pamphlet states:

Selection of the MOE is a subjective process based on how the proponent believes force effectiveness may best be assessed. Its selection is the responsibility of the proponent, with analytical advice when necessary to ensure that the particular MOE can be quantified.

As can be seen, responsibility for the selection of MOE is fixed with the agency desiring the analysis. However, no documents to guide the proponent agency in the selection of MOE have been located. Nevertheless, it can probably be assumed that the testing agency would attempt to eliminate the human element to the greatest extent possible. Otherwise, an inferior item of materiel or a poor organizational or operational concept might be chosen simply because of differences in personnel. A warning against this possibility is found in another document concerned with the type of exercises that should be employed in testing materiel. It is pointed out that free-wheeling, two-sided FTX type of exercises "...instead of tests of the developmental materiel, ... amount essentially to *tests of the people operating the equipment*;"^{8,9} Since it is precisely that which is desired in this research,

⁸US Department of the Army. *Final Report on Special Study, Methodology Investigation For Measures of Effectiveness*, TECOM Project No. 9-CO-OOC-000-007, US Army Armor and Engineer Board, Fort Knox, Kentucky, August 1971.

⁹Italics added by authors.

i.e., to test the people operating the equipment, the excellent guidance provided in TRADOC PAM 11-8 is simply not suitable for personnel or training evaluations.

TRADOC PAM 71-10, "Cost and Training Effectiveness Analysis Handbook," discusses Measures of Training Effectiveness (MOTE) at some length. However, it clearly states that the analyst will have to develop his own. For example, the publication states: "At the present time there appears to be no universal, on-the-shelf MOTEs for CTEA. If they exist, CTEA experience has not been sufficiently accumulated to identify them." The document does, however, suggest sources of information which are described as being either theoretical, empirical, or analytical in nature. It also suggests that typical MOTEs are hit accuracy, pretraining/posttraining changes in performance, navigational error, performance retention, rate of skill acquisition, and correctness of decision. This listing is by no means intended to be exhaustive, and it is still left to the analyst to decide which MOTEs are appropriate for his situation. Even assuming some of the above listed are judged appropriate, the analyst must still decide on what quantity of each is minimally acceptable. For example, for "hit accuracy," he must decide what percentage of hits, or what mean miss distance constitutes effective performance. Hopefully, guidance on these matters can be found in the theoretical, empirical, and analytical sources referred to earlier, but much still remains for the analyst to do. In brief, this pamphlet outlines a methodology for the development of MOE, but leaves much to the judgment, ingenuity, and hard work of the analyst. Therefore, its immediate usefulness in the present research is limited.

Literature concerned with MOE is relatively plentiful. In fact, a bibliographic search of literature available through the Defense Documentation Center (DDC) revealed 149 documents which used either the term "Measure of Effectiveness" or "Measures of Effectiveness" as an identifier. However, most of these proved to be only marginally relevant. The vast majority were concerned solely with hardware parameters (e.g., mean miss distance of a bench-fired weapon). Those concerned with operational effectiveness tended to be highly specific to both hardware and operational situations (e.g., see Hammell, et al.¹⁰). Those concerned with training effectiveness tended to be either oriented toward individual training, or were very broad and theoretical in nature (e.g., see Lyons¹¹ or Bond and Rigney¹²). This does not mean that there was no relevant information in these reports. Many of the notions discussed, problems encountered, and MOE described provided considerable food for thought. However, the information useful to this present effort was largely general or theoretical in nature, and constituted only minor portions of some of the reports.

A few reports, some located through bibliographic search and some through other sources, dealt specifically with the development of MOE

¹⁰T. J. Hammell, C. E. Gasteyer, and A. J. Pesch. *Advanced Officer Tactics Training Device Needs and Performance Measurement Technique - Volume I*, TR:NAVTRAEQUIPCEN 72-C-0053-1, General Dynamics Corporation, General Boat Division, Groton, Connecticut, November 1973.

¹¹J. D. Lyons. "Measuring Effectiveness: Quality Control of Training," Paper for New York University First National Annual Training in Business and Industry Conference, New York City, March 1972. (Included in HumRRO Professional Paper 16-72, Human Resources Research Organization, Alexandria, Virginia, July 1972.)

¹²N. A. Bond, Jr., and J. W. Rigney. *Measurement of Training Outcomes*, Technical Report No. 66, Behavioral Technology Laboratories, University of Southern California, Los Angeles, California, June 1970.

for assessing performance of crews or larger teams. A very few dealt specifically with tank crews or tank platoons. All of these were considered to be highly relevant. However, the more recent works dealing with tank crew or platoon performance were devoted almost exclusively to gunnery. In addition, they were essentially progress reports, indicating that the work on MOE was as yet incomplete.

Without further belaboring the point, after examining the available literature and contacting other agencies involved in armor research, it became obvious that the approach to the problem would have to be changed. There was no set of MOE in current use as implied in the first objective. In fact, the gunnery tables, especially Table VIII, appeared to be the predominant and only consistently used MOE for crew evaluation.¹³ Despite the fact that Table VIII has obvious faults,¹⁴ there are simply no other accepted measures available to commanders. Furthermore, virtually all of the work in progress is also directed toward the gunnery functions. Therefore, the second of the original objectives is reduced to the determination of critical functions outside of gunnery. None of these other critical functions appear to be evaluated at present. The third objective, that of proposing a research program to develop the necessary information to derive MOE, remains unchanged. However, it takes on increased significance, as it now appears that this could be a truly major research effort.

¹³J. A. Larson, W. K. Earl, and V. A. Hanson. *Assessment of US Tank Crew Training*, TCATA Test Report No. FM 331, Final Report (23 March 75 - 15 March 76), Headquarters, TRADOC Combined Arms Test Activity, Fort Hood, Texas, July 1976.

¹⁴P. F. Gorman. "Trends in the Army's Training System," Presentation made to the Army War College, Fort Leavenworth, Kansas, 21 January 1977.

After examining the literature and discussing mutual interests with other interested agencies, a new approach to the problem for this phase of the research was chosen. It was decided that the first phase should be a study and discussion of:

- a. The problems associated with the development of MOE for team evaluations.
- b. Current approaches to training and evaluation of teams.
- c. Research priorities for the development of tank crew MOE.

The remainder of this chapter is divided into sections which correspond to the three areas listed above.

Problem Areas

Defining effectiveness. In his discussion on the meaning of effectiveness, Hale¹⁵ takes a historical look at MOE for one of our simplest weapons -- the rifle. He points out that originally accuracy was the primary MOE. Accuracy was operationally defined as the percentage of rounds that could be placed in a given size circle at a specified range when the weapon was bench fired. Somewhat later, rate of fire was included as an MOE. According to Hale, it was not until around 1960 that the number of MOE began to expand significantly. It was realized that a highly accurate rapid fire weapon was of little value unless it were completely functional. If the weapon malfunctioned frequently, or required excessive repair time, its value would be greatly limited. Therefore, the concept of "availability" came into being as an MOE.

¹⁵D. R. E. Hale. "The Selection of Measures of Effectiveness For Small Arms Experiments," Masters Thesis, Naval Post Graduate School, Monterey, California, March 1974.

Measures of availability such as Mean Time Between Failures (MTBF) and Mean Time to Repair (MTTR) were derived. However, the primary reason for the proliferation of MOE was the recognition that effectiveness was mission dependent. For example, the weapon characteristics desirable for a sniper rifle are quite different from those required for a weapon designed primarily for suppression. In selecting a rifle, a sniper would be primarily interested in accuracy and range, but would not be too concerned about rate of fire. On the other hand, the soldier with a suppression mission would be very concerned with rate of fire. However, his view of and requirements for availability would be quite different. A rifle which malfunctioned on the average of once for every 200 rounds fired might seem highly available to the sniper if repair could be easily effected. However, such a weapon might seem woefully inadequate to the soldier attempting to keep the enemy pinned down or trying to repulse an attack.

As can be seen from the above example, defining and selecting criteria of effectiveness is not an easy task. The magnitude of the problem increases even further with increases in the complexity of the weapons system. For example, Single Shot Kill Probability (SSP_k) is a frequently employed MOE for antiaircraft missiles. However, consider the problem of trying to choose the more effective system between a missile and an antiaircraft gun system. SSP_k is obviously not a suitable criterion for comparing the two systems. The operations researcher might choose a measure such as the number of kills per 100 target passes as more reasonable. However, employing this criterion alone, the missile system would undoubtedly still prove more effective. This measure alone is simply

not adequate upon which to base a final judgment. The cost of the missile system per target pass is likely to be many, many times that of the gun. Therefore, the number of systems which can be deployed would be fewer. It follows then, that with thinner assets, area coverage would likely be less with the missile system. The question then is whether the missile system would actually provide more protection. Also, the missile system is likely to be much more difficult to support logistically, thus greatly reducing its availability. Therefore, if the decision maker takes into account cost, availability, and area coverage, he may conclude that the gun system is actually the better choice despite its smaller kill probability per target pass. Unfortunately, there are no strict agreed upon guidelines for choosing MOE or for weighting them in a final decision.

While the above example was hypothetical, the factors discussed are nevertheless real. An actual example cited by both Hale¹⁶ and Zophy¹⁷ serves to illustrate this fact. In the early phases of WWII a great many merchant vessels were damaged or even destroyed by aircraft attacks. As a consequence, merchant vessels were equipped with antiaircraft guns and crews. After a period of time it was discovered that only four percent of the attacking enemy aircraft were actually shot down. This led some to conclude that the systems were ineffective on ships and could be better employed elsewhere, where kill rates were higher. Employing this MOE, the decision seemed inevitable. However, further

¹⁶*Ibid.*

¹⁷F. G. Zophy. "Methodology for the Evaluation of Air Defense System Effectiveness," Masters Thesis, Naval Post Graduate School, Monterey, California, March 1975.

examination of the data revealed that the antiaircraft fire greatly reduced the lethality of the enemy attack. In fact, the inclusion of antiaircraft weapons virtually halved the probability that a ship would be sunk. Viewed in this light, the systems were considered highly effective.

The above discussions should suffice to demonstrate that the selection of the wrong MOE, or the exclusion of critical MOE, can lead to the wrong decisions about effectiveness. Yet, the selection of MOE is largely an intuitive process. And, all too often, it is feared, intuition is guided more by expedience than by logic. That is, the MOE selected are those which are most easily measured.

Although the foregoing discussion centered on MOE for weapons system effectiveness, the same problems of definition and selection exist in assessing the effectiveness of individuals, crews, or even larger units.

Defining team effectiveness. In the past our attempts to assess effectiveness have been directed almost exclusively to either hardware, as discussed above, or to individuals performing specific jobs. Large-scale scientific approaches to the measurement of individual job performance in the military began during WWI. The US Air Force pioneered this effort. Techniques for analyzing jobs into tasks and subtasks were developed. Normally, those tasks which were highly critical, performed frequently, and performed early in the job environment were selected for training. The remaining tasks were left for On-the-Job Training (OJT). Individual performance was assessed by measuring actual performance on selected tasks. The individual was given a task, all of the necessary

equipment, a list of conditions under which the task was to be performed, and the standards by which he would be judged. The techniques and procedures for accomplishing these processes are well worked out and documented (e.g., TRADOC PAM 350-30¹⁸). Unfortunately, comparably detailed procedures have not been developed for the specification and analysis of jobs to be performed by larger units such as crews, though guidance was provided in TRADOC PAM 350-11.¹⁹ As a member of a crew, the individual does not perform in isolation. Rather, he performs in the context of some larger operation. He must not only be able to perform each of his prescribed tasks to a predetermined criterion, he must also recognize the stimuli which require the tasks to be performed, must perform the tasks in the correct sequence, and must interface with other individuals as required. As a crew member, the individual functions as a part of a total system involving equipment and other personnel. The effectiveness of this system is dependent upon the successful performance of all the individuals involved, working not in isolation but as a team. The measurement of system performance or effectiveness where such interdependency exists has been given serious consideration only recently.

One of the problems associated with the evaluation of team effectiveness has been the inability of investigators to agree on what differentiates team and individual tasks. Most investigators agree that it is wasteful of effort to measure performance in a team context when

¹⁸ TRADOC PAM 350-30. *Interservice Procedures for Instructional Systems Development*, US Army Training and Doctrine Command, Fort Monroe, Virginia, August 1975.

¹⁹ TRADOC PAM 350-11. *Training: Systems Engineering of Unit Training*, US Army Training and Doctrine Command, Fort Monroe, Virginia, January 1973 (not current).

the performance is actually nothing more than an aggregate of individual performances. Individual job skills can almost always be measured more easily, completely, and cost effectively through individual job performance tests. It is felt that measurement of performance in a team context should be reserved for only those tasks which are truly team tasks, that is, tasks which require cooperation or coordination to the extent that skills must be practiced in a team situation in order to be optimized. Efforts to differentiate between team and individual tasks have centered around such words as "cooperation"/"coordination" and "interdependence." As a background for discussion of this problem let us consider some distinctions made by Alexander and Cooperband²⁰ in their discussion of models for team training. They refer to team training paradigms as being either "stimulus-response" or "organismic" in nature. Stimulus-response models call for "established" task situations. That is, the sequence of task performance and the activities involved can be almost completely specified. Also, the assignment of task functions among crew members and the equipment they operate are virtually fixed. Tasks in the organismic model are referred to as being "emergent." In emergent situations, decision making, problem solving and sharing come to the forefront. The sequence of operations is not fixed, and the allocation of functions is variable. An example of an established task situation would be mail sorting assigned to two postal workers, one of whom is to sort mail by states, and the other of whom is to sort the mail for one state by zip code. Errors made by the first

²⁰L. T. Alexander and A. S. Cooperband. *System Training and Research in Team Behavior*, Technical Memorandum 2581, System Development Corporation, Santa Monica, California, August 1965.

worker can be corrected in part by the second. However, the functions of each are well defined, coordination is minimal, and the actions of each are virtually completely specified. In the present research, an example of an emergent situation might be tank crew target acquisition. All members of the crew are involved. Neither the responsibilities of each member nor the activities required of any individual can be precisely specified. The crew's job is to detect targets, but who accomplishes the detection is not specified, and the method is only loosely implied. However, as will be seen later in this section, not all investigators would conclude that this example is a team task.

In discussing established versus emergent situations, Hall and Rizzo²¹ essentially conclude that tasks performed in established situations are not really team tasks. They feel that overall team performance in established situations is simply the sum of the performances of the individual team members. One team member cannot completely make up for the shortcomings of another, as activities are specifically allocated to team members. Outstanding performance (e.g., significant time savings in accomplishing an individual activity) on the part of some members may in part compensate for deficiencies in others, but basically, every member of the team must perform satisfactorily if overall team performance is to be satisfactory.

For a performance to be truly a team effort, Alexander and Cooperband²² stress that cooperation is necessary. They state:

²¹E. R. Hall and W. A. Rizzo. *An Assessment of US Navy Tactical Team Training: Focus on the Trained Main*, TAEG Report No. 18, Training Analysis and Evaluation Group, March 1975.

²²Alexander and Cooperband, *op. cit.*

Learning to cooperate means learning the strengths and weaknesses of one another, learning when the others want help and when they do not want it, learning to pace one's activities to fit the needs of all, and learning to behave so that one's actions are not ambiguous.

According to this concept, activities are not specifically allocated, and decisions about who does what are dependent upon the individual skills of the team members and the particular situation. For example, football teams adjust to each new opponent by changes in both personnel and tactics in order to take advantage of known or suspected weaknesses. In other words, the team functions in whatever manner it feels best to accomplish its objective -- that of winning the game.

Briggs and Johnston²³ would undoubtedly agree with the above analysis. However, they complicate the problems of definition even further through their discussion of the terms "serial" and "parallel." In serial tasks, a second action is dependent upon the performance of a first. The present authors feel that an example of a serial task can be drawn from baseball. Suppose the batter hits a ground ball toward the shortstop. It is the shortstop's job to field the ball and throw it to the first baseman. It is then the first baseman's job to catch the ball and put a foot on the base. However, notice that if the shortstop misses the ball, the first baseman actually does not get involved at all, nor is there any action he can take to ensure overall team effectiveness. In serial tasks, the success of the team is dependent upon the success of each individual doing his job properly in sequence.

²³G. E. Briggs and W. A. Johnston. *Team Training*, Final Report, February 1966-February 1977, NAVTRADEVCEEN-1327-4, Naval Training Devices Center, Orlando, Florida, 1967.

According to Briggs and Johnston,²⁴ successful performance of a parallel task requires everyone on the team to do his job at the same time, but individually. For example, engaging in a "tug-of-war" is the present authors' conception of a parallel task. The effort of individual A is not dependent upon the effort of individual B, yet both may contribute equally to team success. It is true that team success may be a function of their cooperation with a team captain in response to his order to "heave." However, the optimum performance of member A is still largely independent of the performance of member B. Logically, it does not seem that A and B cooperate or are interdependent. Therefore, by the definitions proposed, there is no "teamwork" involved, so there is little reason for A and B to train together. However, teamwork may be involved between the captain and the individual members, as exact timing may be crucial to success. So in one sense, a tug-of-war team is a team, in another, it is not.

Let us now return to the tank crew in its attempts to acquire a target. Is this performance a parallel performance, that is, does each member do his job completely independent of the others? Some would answer "yes," others "no." Those who say "yes" would point out that each individual scans independently, that specific sectors can be assigned, and therefore, no teamwork is involved. Those who say "no" would point out that search sectors are not necessarily fixed. A crew can adapt to each others' shortcomings by overlapping search sectors. However, each and every crew may work differently -- making target acquisition cooperative. Therefore, target acquisition fits the pre-

²⁴*Ibid.*

dominant definitions of a team task. Both points of view can be defended, but neither makes the task of deriving tank crew MOE any less difficult.

Personal communications²⁵ from other investigators involved in the training and evaluation of tank crews/platoons have indicated other areas where the line between crew and individual tasks is "fuzzy." For example, consider the overall crew task of firing on the move. The driver must obviously maintain speed, and keep the tank as stable as possible in all three planes. The question is whether this is an individual driver skill, or whether performance is dependent upon an interaction between the driver and tank commander, and/or the driver's knowledge of how this particular crew performs in this situation. No attempt will be made to answer this question at this point. It is posed simply to indicate the range of disagreement between well-informed investigators concerning the distinction between team and individual performances.

From the above discussion it may be concluded that there are no clear-cut criteria for distinguishing between individual and team tasks. This presents a problem for the present research since team (in this case, crew) MOE are the object of concern. It seems undesirable to propose crew performance measures for tasks which are actually only aggregations of individual task performances. However, failure to identify performances which are in reality team performances might constitute an even greater error. At present no solution to this problem of definition has been achieved. The reader interested in pursuing

²⁵Discussions with Dr. N. K. Eaton, Dr. D. W. Bessemer, and Dr. R. W. Bauer, ARI Field Unit, Fort Knox, Kentucky, March 1977.

this problem in greater depth should consult Wagner, et al.,²⁶ or Hall and Rizzo.²⁷

Despite disagreements on what kinds of tasks are individual and what kinds are team tasks, Wagner, et al.,²⁸ concluded in their review of the literature that team members must first master their individual skills for a team to perform effectively. Therefore, individual training and evaluation should precede team training in any case.

Problems with numbers. In attempting to fully describe the job situations of the tank crew in gunnery, Kraemer, Boldovici, and Boycan²⁹ derived a set of 11 classes of conditions or variables that could affect the crew's capability to successfully engage targets. Some examples of these classes and the number of levels identified for each of these classes are shown in Table V-1. The term "levels" as employed by the writers refers to subclasses within the main class. For example, there are six kinds of ammunition available for use by the M60A1 crew. Therefore, this variable has six levels. The determination of the number of levels for these discrete variables such as types of ammunition, fire delivery method, crew members, and weapons was obvious as they represent discrete "real world" conditions. The determination of the levels for continuous variables such as range was done on logical grounds, and was based on the effective ranges of the weapons, the fire control instruments, and the types of ammunition that are typically employed at

²⁶Wagner, et al., *op. cit.*

²⁷Hall and Rizzo, *op. cit.*

²⁸Wagner, et al., *op. cit.*

²⁹Kraemer, Boldovici, and Boycan, *op. cit.*

Table V-1

Conditions and Levels Within Conditions*

<u>Conditions</u>	<u>Levels Within Conditions</u>
Weapon	Main Gun Coaxial Machinegun Caliber .50 Machinegun
Fire Delivery Method	Battlesight (non-precision for machineguns) Precision Range Card Range Card Lay to Direct Fire
Firing Vehicle Motion	Stationary Moving
Target Visibility	Visible Without Artificial Light Visible With Artificial Light Not Visible
Target Range	<500 meters 500-900 meters <900 meters <1100 meters 1100-1600 meters 500-3200 meters 1100-2300 meters 1100-3200 meters ALL

*Condensed from FIG. 2, page 2, R. E. Kraemer, J. A. Boldovici, and G. G. Boycan, *Job Objectives for M60A1AOS Tank Gunnery*, Research Memorandum 76-9, Human Resources Research Organization, and Army Research Institute, April 1976.

various ranges. If a tank gunnery objective were written for all possible combinations of levels, a total of 1,679,616 objectives would result. However, the great majority of combinations are unrealistic (e.g., a moving bunker) and could be discarded. Judicious combinations of other levels reduced the total number of realistic combinations to 225. After extensive review by experts, the number was increased to 240.³⁰ More recently, the list was expanded to 266.³¹ To test a crew's ability to perform all of these job objectives would be time consuming, to say the least, and it must be remembered that these objectives cover only tank gunnery. Description of the tank crew's total job would require considerably more job objectives. Obviously, it is not feasible to measure job proficiency on all job objectives. Tests designed to measure effectiveness will be able to address only a limited number of the objectives. This need to select a limited subset of job objectives for measurement is likely to produce unfortunate results. Training is almost certain to be concentrated on those areas which will be tested, to the detriment of other aspects of the job. As a result, tank crews which appear proficient during the testing may actually be unable to perform a number of tasks that may be necessary on the battlefield. This error could be avoided by designing a large number of tests, each of which covered only selected aspects of the job, but in toto, covered all of the jobs. Crewmen would not be advised in advance as to which tests or set of tests they would be administered. Therefore, training

³⁰J. A. Boldovici, G. R. Wheaton, and G. G. Boycan. *Selecting Items For a Tank Gunnery Test* (Draft Interim Report), US Army Research Institute for the Behavioral and Social Sciences, Arlington, Virginia, August 1976.

³¹Personal communication from G. G. Boycan, Army Research Institute, Arlington, Virginia, May 1977.

could not be slanted to the test. However, the development of tests is expensive, and the resource requirements for support of a large number of possible tests would be obviously greater than for a single version. Hence, this alternative is not attractive either. At the present time, satisfactory solutions to this numbers problem have not been found.

Reliability and validity. Measures of effectiveness employed in evaluating military training or assessing operational readiness are frequently referred to as intermediate criteria. They are used in lieu of the ultimate criteria -- the ultimate criteria being actual combat performance. To be of any value, the MOE must be highly predictive of how crews would perform these functions in actual combat. That is, it must have predictive validity.

For an MOE to be valid, it must also be "reliable." That is, it must measure whatever it measures with consistency. A reliable test (whether an MOE or other) will produce essentially the same results for each crew tested whether it is administered today, tomorrow, or the day after. For example, if Table VIII scores are reliable, a crew that scores 1400 points today should score in the near vicinity of 1400 points tomorrow if the test is repeated. Unless a test yields repeatable results (i.e., is reliable), the test cannot be valid, that is, it simply will not predict combat performance very well. If a given crew scored 1400 points on one occasion and 400 on another, there would be no way of knowing which (if either) of the scores was the "true" indication of the crew's combat gunnery capability. Both scores obviously cannot be indicative. Therefore, reliability is a prerequisite to validity.

Unless we validate an MOE by comparing scores with actual combat performance data, we can only assume its validity. Hopefully, we shall never have the opportunity to test validity, in this manner. However, we can estimate the reliability of an MOE. Finding that it is reliable does not guarantee its validity, but finding that it is not reliable does guarantee that it cannot be valid. Therefore, for the present we can only assure ourselves that any MOE employed are reliable, and hope that they are valid. For a more detailed discussion of reliability and validity, the reader is referred to Nunnally.³²

Since Table VIII is by far the most frequently employed MOE for tank crews,³³ it is essential that we know it to be reliable. However, the actual reliability of Table VIII has apparently never been determined. The only data located which even bear on the subject are those presented by Baerman and Eaton.³⁴ They found a correlation of $r = .68$ between supervisors' ratings of tank commander motivation and Table VIII scores.³⁵ Since the correlation between two variables can be no higher than the reliability of the less reliable of the two variables, this result would indicate that the reliability of Table VIII is at least 0.68. However, the Table VIII scores employed by Baerman and Eaton were

³²J. C. Nunnally. *Psychometric Theory*, New York: McGraw-Hill, 1967.

³³Larsen, Earl, and Henson, *op. cit.*

³⁴V. P. Baerman and N. K. Eaton. "Crew Assignment and Training," *Armor*, January-February 1977, 50-53.

³⁵Personal communication from Dr. N. K. Eaton, ARI Field Unit, Fort Knox, Kentucky, March 1977.

obtained in a somewhat different manner than usual.³⁶ All crews fired two rounds at each target, regardless of whether they were perceived to have obtained a first-round hit. In addition, plywood targets rather than cloth targets were employed, and scoring of hits was accomplished by closeup examination of the targets after each crew had completed its run. It was, of course, not possible to determine whether a single hit was achieved on the first or second round, so any hit was given the same score. While these changes may not appear to be drastic, it seems probable that they had a significant effect on the scoring. For example, the investigators originally had asked the observers riding the tanks to score hits, which is part of the normal procedure for scoring Table VIII. However, this practice was discontinued shortly thereafter when it was found that the observers' hit determinations were at variance with those made by the team closely examining the plywood targets. In other words, had the normal scoring procedures been employed, the scores obtained might have differed significantly from those resulting from the procedures actually used. It would appear that it is very difficult for the observer to determine if a hit has been made, and it is therefore likely that his judgment will be subject to considerable error. In such cases, reliability of derived scores is typically low. Therefore, the reliability of Table VIII scores, when obtained in the manner described in FM 17-12-5,³⁷ is likely to be unacceptably low. At the very least,

³⁶ Personal communication from Dr. N. K. Eaton, ARI Field Unit, Fort Knox, Kentucky, March 1977.

³⁷ FM 17-12-5. *Tank Gunnery Training*, US Army Armor School, Fort Knox, Kentucky.

it seems that priority should be given to determining the actual reliability of Table VIII scores through test/retest procedures.

One further observation can be made concerning the Baerman and Eaton work. There can be little doubt that the techniques employed by these researchers resulted in more accurate data on actual hits than those normally employed. Therefore, it seems that the Army could improve its crew gunnery skills evaluations by investing a few more resources in Table VIII scoring. At least the reliability would likely be improved.

Although objective scoring procedures usually result in improved reliability, they do not always guarantee it. For example, Hemphill and Sechrest³⁸ examined the reliability of a cherished Air Force MOE with high assumed validity -- that of crew bombing scores. Scores were derived by measuring the miss distances between the points of impact and the target. The crew with the lowest mean miss distance naturally received the highest score. Since the miss distances could be measured quite accurately, there was no question but that the scoring was objective. However, Hemphill and Sechrest were able to obtain data on a number of crews who completed bombing runs on two separate occasions. They found the score to be very unreliable. In other words, a crew's score on the first run was not predictive of its score on the second run. Therefore, despite the objectivity in scoring and the previously presumed high validity, the bombing score proved to be a worthless indicator of crew proficiency.

³⁸J. K. Hemphill and L. J. Sechrest. "A Comparison of Three Criteria of Aircrew Effectiveness in Combat Over Korea," *Journal of Applied Psychology*, 1952, 49, 323-327.

In many cases, an unreliable measure can be made reliable if sufficient data are obtained. For example, if six heads and four tails are obtained in ten flips of a coin, the evidence that the coin is biased is very meagre. However, if 600 heads are obtained in 1000 flips, the evidence for bias is quite substantial. Many types of performance data are similar in that a large body of data must be obtained before any faith can be put in the results. Data on target detection in field situations falls into this category. The time elapsed between the moment Line-of-Sight (LOS) is achieved and the target is detected is the usual performance measure. Intuitively, it would be fool-hardy to judge a crew's ability to detect targets on the basis of a single trial. Intra-crew variability is simply too great. The question is: "How many trials are needed"? The same question can be asked concerning any number of other job functions including gunnery performance. Few officers would be willing to judge a crew's main gun gunnery ability on the basis of a single round, but how many rounds are needed? Are enough rounds fired in Table VIII to make a judgment, especially considering the number of conditions involved (e.g., stationary tank/stationary target, stationary tank/moving target, etc.)? Can a judgment be made concerning capability in both Battlesight and Precision engagements since the crew has a choice of mode and may use one almost to the exclusion of the other? In other words, are enough rounds fired in any single condition of tank movement, target movement, and engagement mode to justify a statement that the crew is or is not qualified in that condition? Only research into the reliability of gunnery measures can answer these questions.

Steinheiser and Snyder³⁹ present a very interesting though technical discussion of great relevance to the reliability questions concerning Table VIII. Part of their discussion centers around the likelihood that a crew will be considered to be proficient when it is not, or, that it will be considered nonproficient when it is. It is beyond the scope of this report to go into the theory and assumptions behind this work, but a brief summary of one of the notions discussed will be presented. To expedite an understanding, a small portion of a table presented in their text is shown below as Table V-2. This table may be interpreted as follows: (1) A score of 70 percent is required to receive a "passing" grade, (2) there are 18 items (exercises, parts, whatever) in the current Table VIII, (3) 13 items must be passed to achieve 70 percent overall, (4) five percent of the crews whose true level of functioning (i.e., the average score they would receive if they fired Table VIII

Table V-2

Probability of Misclassification

Required Mastery Level	Table VIII Length	Passing Score	True Level of Tank Crew Functioning				
			50%	60%	70%	80%	90%
(1) 70%	(2) 18	(3) 13	(4) 5	(5) 21	(6) 47	13	1

over and over) is only 50 percent would by chance score 70 percent or more on any single test, and therefore, be considered proficient, (5) 21 percent of the crews whose true level of functioning is only 60 percent would by chance score 70 percent or more on any single test, and therefore,

³⁹F. Steinheiser, Jr., and C. W. Snyder, Jr. "Score Quality Issues Related to Individual and Weapon Crew Criterion-Referenced Performance Tests," Presented at Military Testing Association Conference, October 1976.

be considered proficient, and (6) 47 percent of the crews whose true level of functioning was 70 percent would by chance score less than 70 percent on any single test, and therefore, be judged as nonproficient, even though they actually were proficient at the minimum acceptable level. The likelihood of misclassifications of crews whose true level of functioning was 80 or 90 percent can also be seen in the table. It is obvious from Table V-2 that the likelihood that a given crew would be misclassified on the basis of a single Table VIII exercise is quite high unless they were very proficient or exceedingly nonproficient. Also, it must be remembered that for this example, Steinheiser and Snyder considered all items in Table VIII to be of equal importance. That is, a crew would be considered proficient if they passed any 13 items. Success in any particular combination of tank movement, target movement, or engagement mode is not considered. A tank crew could be woefully inadequate in one combination and still be considered proficient by doing well in all others.

Data will not be presented, but Steinheiser and Snyder show that errors of misclassification can be reduced by doubling the length of Table VIII to 36 items. However, crews near the borderline of the minimum acceptable proficiency level are still likely to be misclassified.

In summary, those responsible for the evaluation of tank crews must give serious consideration to the reliability of Table VIII or any other MOE that is employed. Furthermore, they must realize that the validity of these MOE can only be assumed.

Resources. At the time of this writing, the Army is experiencing one of the longest and most severe periods of austerity in its recent history. Total strength is lower than in any recent period, and expendables such as ammunition and fuel are stingily allocated. Yet, as has been hinted in several of the previous sections, adequate evaluations require considerable manpower, time, and materiel resources. In the previous section on Reliability, serious questions were raised concerning the adequacy of Table VIII for the evaluation of the several aspects of gunnery. It was also pointed out that doubling the table's length would result in fewer proficient crews being misclassified as nonproficient and vice versa. Of course, doubling the length, or even adding any items would naturally increase resource requirements. It was also pointed out in another section that 266 job objectives had been derived for gunnery alone, and that considerably more resources would be required to test all objectives than are currently being spent.

In less austere times, Baker and Cook⁴⁰ painstakingly constructed a "Tank Platoon Combat Readiness Check." The final checklist, including instructions to the examiner, was approximately 90 typewritten pages in length. The authors also pointed out that the entire evaluation took approximately 30 hours to administer, and required the use of "aggressor" forces. At the present time, most commanders would consider the resources required for conducting such an evaluation to be out of the question.

⁴⁰R. A. Baker and J. G. Cook. *The Development and Evaluation of the Tank Platoon Combat Readiness Check*, Research Memorandum, Human Resources Research Organization, Alexandria, Virginia, April 1964.

More examples could be cited, but the point should already be clear. The Army cannot adequately evaluate team performance employing the techniques it has used in the past unless additional resources can be found. However, there are efforts in progress designed to reduce overall resource requirements without sacrificing training effectiveness or evaluation adequacy. Simulation techniques, for example, are being employed with increasing frequency, especially in training. The associated reduction in resources used for training may release resources to be used for other purposes such as evaluations. Some simulation research of great relevance to this present effort was conducted by Powers, et al.⁴¹ As part of this effort, four groups of tank gunners were trained employing 100 percent, 66 percent, 33 percent and 0 percent live-fire. There were no differences between the hit percentages of the four groups in a live-fire posttraining test. Since the 100 percent group fired 24 live rounds in training, it appears that considerable ammunition could have been saved with no loss in training effectiveness. Similar results were obtained with two other weapons systems. Nevertheless, the authors did conclude that some live-fire training should be conducted. However, based on the results obtained, it must be concluded that the use of simulation could greatly reduce ammunition requirements for training itself, releasing resources for training and operational effectiveness evaluations.

Although the development of synthetic performance tests is still in a stage of infancy, this technique holds promise for further reduction

⁴¹T. R. Powers, M. R. McCluskey, and D. F. Haggard. *Determination of the Contribution of Live Firing to Weapons Proficiency*, Final Report FR-CD(C)-75-1, Human Resources Research Organization, Alexandria, Virginia, March 1975.

of resource requirements for some aspects of evaluation.^{42,43} Synthetic performance tests are a type of simulation. However, the notions behind them are somewhat different than for most simulations. In developing a synthetic performance test, all of the individual behaviors involved in the total performance are detailed. Next, an inexpensive means of testing each behavior is sought. The physical fidelity of the test in terms of the actual job may be quite low -- so long as the behaviors are the same. The set of tests is then "synthesized" into a single performance test. Finally, the validity of the test is determined by comparing it to actual job performance. If the synthesized test proves valid, it can be employed as an inexpensive substitute for a true job performance test, at least during early training evaluations. Again, resources could be conserved to adequately test those critical aspects of performance for which no good substitute for actual job performance could be found.

The need to know exactly how effective our forces are was implied by MG Gorman when he challenged Army trainers:

To train the Army to win on the first battlefield of the next war against an enemy that outnumber us, against an enemy whose weapons will be as good as or nearly as good as those that we possess....⁴⁴

⁴²W. C. Osborn. *An Approach to the Development of Synthetic Performance Tests For Use in Training Evaluation*, Professional Paper 30-70, Human Resources Research Organization, Alexandria, Virginia, December 1970.

⁴³W. C. Osborn and J. P. Ford. *Research on Methods of Synthetic Performance Testing*, Final Report FR-CD(L)-76-1, Human Resources Research Organization, Alexandria, Virginia, April 1976.

⁴⁴W. E. DuPuy and P. F. Gorman. "TRADOC Mission and Resources Briefing," Transcript from TV tape, US Army Training and Doctrine Command, Fort Monroe, Virginia.

To accomplish this mission, trainers can ill-afford to use any but the most effective evaluation techniques. It is the opinion of the present authors then, that the resource problem is not one of whether we expend the resources to properly evaluate, but rather, how we obtain the necessary resources. Simulation, as discussed briefly above, is one approach, but other avenues should also be investigated.

Current Approaches

Not all the current approaches to team training and evaluation found in the literature appear to be adaptable for use with tank crews. Only those which appear to the authors to have some relevance to tank crew evaluations will be discussed in this section. The reader interested in a broader perspective should consult Wagner, et al.,⁴⁵ Larson, et al.,⁴⁶ or Briggs and Johnston.⁴⁷

Before going into particulars, two principal issues which divide evaluators in their approaches need to be discussed. These are the employment of: (a) one- vs. two-sided test situations, and (b) process vs. outcome measurements. The arguments for both sides of these issues are presented briefly below.

One-sided vs. two-sided tests. In a one-sided test (such as Table VIII) the examinees face a relatively structured situation in which the sequence of events is relatively fixed. "Aggressor" forces, if present

⁴⁵Wagner, et al., *op. cit.*

⁴⁶O. A. Larson, S. I. Sander, and J. H. Steinemann. *Survey of Unit Performance Effectiveness Measures*, Technical Report 74-11, Naval Personnel Research and Development Center, San Diego, California, January 1974.

⁴⁷Briggs and Johnston, *op. cit.*

at all, are restricted to specific preplanned activities. In a two-sided test, aggressor forces must be present and typically have few limitations placed on their activities. The advocates of two-sided exercises stress the importance of realism, the opportunities for real-time decision making, and the morale-boosting aspects of competition. They also point out that the inflexibility of one-sided tests makes them easy to train and practice for. Therefore, they feel such tests provide only poor indications of how the participants would actually perform in combat.

Those favoring the one-sided approach to evaluation point to the fact that repetition of the identical circumstances is virtually impossible in a two-sided test. Therefore, no two individuals or crews receive exactly the same test, making it impossible to set exact performance standards or to compare the performance of any two units.

The arguments for both approaches are summarized in an unpublished work by W. W. Yale.⁴⁸ However, he points out that the kind of information desired determines which kind of test is most suitable. For example, if exact times are needed, such as the time to fire after LOS to a target is achieved, a one-sided test should be employed. Knowledge of the exact moment the target appeared would be virtually impossible in a two-sided test. One-sided tests are also necessary if live-fire is required.

Two-sided exercises are considered essential when targets must be generated. For example, a two-sided exercise would be necessary if the MOE were to be the ratio of friendly to threat casualties.

⁴⁸ Based on notes provided by Dr. C. O. Nystrom, ARI Field Unit, Fort Hood, Texas.

As can be seen, each approach has both positive and negative aspects. These should be kept in mind in the discussions of specific programs which follow the discussion of process vs. outcome measurements.

Process vs. outcome measurements. Stated very simplistically, "process" measurements are concerned with an evaluation of all of the actions taken during an engagement, but are not particularly concerned with the final outcome. "Outcome" measurements are not concerned with the procedures involved or the progress of the engagement, but only in who wins and who loses.

Osborn⁴⁹ is an advocate of process measurement. He feels that to be useful, a test must be diagnostic. That is, it must provide information on exactly why a particular aspect of performance was successful or unsuccessful. Hammell, et al.,⁵⁰ state the case for process evaluations as follows in discussing Advanced Officer (AO) tactics training:

...numerous alternative sequences of actions may exist, many of which may be equally plausible for attaining a specific objective. The sequence of actions employed by the AO contains a complex series of evaluations and action selections which are situation intended. The attainment of the ultimate objective may often be irrelevant to the evaluation of the AO's performance. *This hit or miss philosophy, although distinctly meaningful in the operational environment, is inadequate in the training situation.*⁵¹

⁴⁹W. C. Osborn. *Process versus Product Measures in Performance Testing*, Professional Paper 16-74, Human Resources Research Organization, Alexandria, Virginia, October 1974. (Based on paper for Military Testing Association Meeting, San Antonio, Texas, October 1973.)

⁵⁰Hammell, Gasteyer, and Pesch, *op. cit.*

⁵¹*Italics added by authors.*

In other words, Hammell and associates feel that process is the only important aspect of performance in training evaluations. A good decision or action may lead to a poor outcome, but the decision or action should be evaluated on its own merits, and not on the vagaries of future actions by an unpredictable enemy.

Litton Industries, in an unpublished report to ARI, stated the case for outcome evaluations.⁵² The authors felt that tests such as the Army Training Test (ATT) and the Operational Readiness and Training Test (ORTT), now subsumed under the ARTEP, were not satisfactory instruments partly because they emphasized planning and processes over results. They believed that what a unit can accomplish is the ultimate measure of effectiveness. Accomplishments, they felt, could be best evaluated in outcome measures such as friendly/enemy loss ratios and territory gained or lost.

It is obvious that a difference of opinion exists. However, Hammell, et al.,⁵³ while stressing process, do admit that outcome measurements are "distinctly meaningful in the operational environment." Therefore, the type of measure chosen may well depend upon the job held by the evaluator. An S-3 might well choose a process evaluation, a troop commander might well be more concerned with an outcome evaluation.

In the first section of this chapter, the authors of this report hopefully made it clear that they feel an evaluation should cover both process and outcome. The notion that "the operation was a success, but

⁵²Personal communication from Dr. R. T. Root, Unit Training and Evaluation Systems Technical Area, Army Research Institute, Arlington, Virginia, March 1977.

⁵³Hammell, Gasteyer, and Pesch, *op. cit.*

the patient died" is lacking in appeal. We would like to know why the operation was considered a success if the patient died. Similarly, if the patient lived, we would like to know whether the operation was responsible, and if so, why. Both approaches obviously have shortcomings, and these must be taken into account in considering the specific operational training and evaluation programs outlined in the following subsection.

Specific programs. Descriptions of specific programs directed to measuring the effectiveness of teams are outlined below. Most of these techniques were designed to assess performance of larger units than single crews, e.g., platoons or companies. However, these larger units still fall within the definition of a team proposed earlier, and the techniques are considered to be relevant to the present research.

(a) ARTEPs. The Army Training and Evaluation Program refers to a whole body of literature stressing a mission-oriented, performance-based approach which has been under development since 1974. The ARTEPs outline the basic missions that the team should be able to perform to be combat ready. While they do not necessarily require two-sided tests, they are obviously valuable in preparing scenarios for REALTIME and MILES exercises, which will be discussed later in this subsection. They are also oriented toward process evaluations, in that they stress planning and execution above outcome. The ARTEP concept is definitely a step in the right direction. However, the lack of specifics makes it impossible for commanders to set absolute standards. Furthermore, the

standards stated are marred by the use of vague indefinable terms such as "on time," "excessive," and "proper."⁵⁴

The ARTEP concept is new and is constantly being modified. Its eventual form cannot be predicted at this time. It may evolve into a very comprehensive and standardized set of tests, as what it encompasses has not been limited. However, at present, the ARTEP for any military unit suffers from all of the shortcomings described for two-sided tests and tests measuring process only. The ARTEP undoubtedly provides excellent training, but leaves something to be desired in terms of evaluation.

(b) IDOC (Identification of Test Doctrine for Cost/Effective Qualification of Tank Crews). This project has thus far been limited to a study of tank gunnery. At present, 266 tank gunnery job objectives have been identified, and a list of the behaviors or actions required of each crew member in accomplishing each objective has been derived. Work is proceeding to determine the representativeness, generalizability, and criticality of the objectives so that final priorities for measurement can be established.⁵⁵ Hopefully, a set of objectives can be selected which: (a) is representative of the entire range of at least the more critical gunnery tasks, and (b) can be reliably measured within the resources likely to be available. The eventual product of this work will in all likelihood be a recommended new Table VIII. However, many questions need to be answered before standards can realistically and

⁵⁴J. F. Hayes and M. R. Wallis. *ARTEP Validation Report*, US Army Research Institute for the Behavioral and Social Sciences, Arlington, Virginia, 1974.

⁵⁵G. G. Boycan and A. M. Rose. "An Analytic Approach to Estimating the Generalizability of Crew Performance Objectives," Paper presented at the meeting of the Military Testing Association, October 1976.

finally be set. For example, what is the acceptable upper limit of time to fire? Folklore has it that the first round should be fired within five seconds (battlesight) after a target is detected. However, the present authors were unable to trace the origin of this figure. Whether it is based on times obtained by well-trained crews, whether it is based on a knowledge of times achieved by potential enemies, or whether it is simply an opinion is not known.

Hopefully, the IDOC effort will result in a better measure of tank crew qualifications for gunnery. However, it is currently focused only on gunnery, and a combat-ready crew is obviously required to perform many other kinds of tasks.

An ARI effort closely related to IDOC is now in progress in Europe. However, rather than attempting to derive objectives for gunnery in general, this effort is aimed at deriving objectives and a training program for the USAREUR Table VIII as it now stands.⁵⁶ The ultimate objective of the program is to design training that will maintain gunnery skills between opportunities for live-fire. Because of limited space, opportunities for live-fire or even maneuver are extremely limited in Europe.

(c) REALTRAIN. The REALTRAIN effort grew out of a need to provide a realistic, low-cost tactical training and evaluation technique for use in Army combat training. In essence, it is a two-sided, free-

⁵⁶E. E. Miller and J. F. Hayes. *Analysis of Tank Crew Performance Requirements for Multiple-Target Engagements*, ARI Research Memorandum, General Research Corporation, and US Army Research Institute for the Behavioral and Social Sciences, December 1976 (in process).

play engagement simulation technique. How the exercises of relevance to armor are conducted has been described by Shriver, et al:⁵⁷

For the M60 tank, the controller's telescope is mounted in the breech of the main gun. When the controller in the tank determines that the main gun is centered on a target at the time of simulated impact, he assesses a casualty. The controller then radios the number of the tank or other vehicle that was hit to the controller on the other side who removes the vehicle from action.

Artillery fire is realistically simulated by detonating artillery simulators at the actual point requested (by infantry personnel) based on map coordinates, indirect fire "call" procedures and "times" to impact. The rounds are placed by administrative personnel who are directed by a Fire Direction controller who in turn receives fire requests from the forward observer or unit leader in the simulated engagement. When simulated rounds are detonated by artillery throwers, controllers assess casualties within the "kill radius" of the simulated artillery round and take them out of action.

As can be seen, the primary function of the controller is to assess casualties and remove them from the mock battle. REALTRAIN exercises are therefore primarily product rather than process oriented. "Winning the war" and surviving become the paramount goals. However, records are kept at a Net Control Station, and an After Action Review is conducted with test participants. Therefore, a post hoc look at the processes that might have led to certain actions taken is attempted. Following the After Action Review, senior personnel further analyze the exercise and determine whether remedial training is needed, whether the exercise should be repeated, or whether the exercise should be expanded.

⁵⁷E. L. Shriver, B. L. Mathers, G. R. Griffin, D. R. Jones, L. E. Word, R. T. Root, and J. F. Hayes. *REALTRAIN: A New Method for Tactical Training of Tank Units*, ARI Technical Report S-4, Kinton, Inc., and US Army Research Institute for the Behavioral and Social Sciences, December 1975.

The value of the REALTRAIN approach for unit training can hardly be questioned. Resource requirements are minimal and participants can practice a variety of individual and team skills. Deficiencies will undoubtedly be discovered and remedied, and the "casualties" will live to fight another day. However, as an evaluation technique, REALTRAIN, at least as presently conceived, has a number of shortcomings. First of all, there is still subjectivity involved in casualty assessment. Can an observer looking through a telescope in the breech block of a tank gun reliably determine whether a moving target would be hit? Secondly, as in all two-sided free-play exercises, exact situations cannot be replicated. A decision which turned out badly might well have turned out well against a different enemy. A really poor decision might turn out well because of enemy mistakes. The commander might then tend to repeat the same set of actions when he again faces a similar situation, and likely with disastrous results. In other words, outcomes are partly dependent upon chance factors, making it impossible to judge the adequacy of decisions and actions in any absolute sense.

In brief, commanders can use REALTRAIN techniques to spot major deficiencies and glaring errors in judgment, but in the opinion of the present authors, the approach is not adequate for assessing overall combat qualification.

(d) UPAM (Unit Performance Assessment Model).⁵⁸ The basic approach involved in this model is to compare "costs" to "achievements."

⁵⁸ The model described was developed by Litton Industries, but no published work could be found. The information presented on the UPAM is based on a personal communication from Dr. R. T. Root, Unit Training and Evaluation Systems Technical Area, Army Research Institute, Arlington, Virginia, March 1977.

A cost might be the number of friendly tanks lost. An achievement might be the number of enemy tanks destroyed. Similarly, casualties among friendly personnel, own supplies expended, destroyed, or captured, and terrain lost would be classified as costs, while enemy casualties inflicted, enemy supplies expended, destroyed, or captured, and terrain controlled would be considered to be achievements. Weights for each cost and achievement were derived employing ratings and regression techniques.

Guides for the employment of the model have been developed for selected kinds of units. The commander employing the model for his unit must size up the situation he intends to play and make certain decisions concerning costs and achievements. For example, he must decide on the minimally acceptable achievement, i.e., the proportion of enemy tanks which must be destroyed. Similarly, he must decide on an acceptable cost for the scenario he wishes to play, i.e., the proportion of friendly tanks which may be lost. After all such decision are made, the "battle" is played, and actual costs and achievements are determined. Procedures are provided for determining whether the unit being evaluated met its overall performance objective. A team might be considered successful without having a favorable ratio of achievements to costs in all categories. For example, a very high ratio of enemy/friendly tanks destroyed might outweigh an unfavorable ratio of enemy/friendly supplies expended, destroyed, or captured.

The model has the advantage of letting the individual commander set his own acceptable cost/achievement ratios for each category. He can tailor these to the particular situation he intends to portray in the

mock battle. If he wishes to determine the ability of a unit to hold a piece of territory "at all costs," his ratios might be quite different than if the unit's objective is to hold the enemy's advance to 10 km in 24 hours.

The model, as the present authors understand it, has appeal. However, the ability of the small unit commander to realistically set costs and achievements for all types of scenarios is questionable. Also, the model appears to be almost totally an outcome model. Provision for determining why a unit failed does not seem to have been made. As a result, feedback to training managers is likely to be minimal. Also, allowing individual commanders to set costs and achievements would make it very difficult to compare the performance of different units, as no two commanders may choose exactly the same standards.

(e) MILES (Multiple Integrated Laser Engagement System).

This system is currently under development. Evaluation by TCATA is programmed to begin soon and continue through FY 1979. The essentials of the system include an eye-safe laser mounted on each weapon, and a sensor mounted on each target. The purpose of the system is to eliminate some of the subjectivity in scoring that is currently a problem in REALTRAIN. If a soldier (or crew) "shoots the sensor on an enemy target, there can be little doubt that a hit occurred.

How well the MILES system can be adapted to unit training and evaluation remains to be seen. Also, how realistically the system can be made to reproduce battlefield results is still a question. For example, damage done to a tank target is dependent upon where the tank is hit. A hit on the side near the rear would undoubtedly immobilize

the tank, but not necessarily kill the crew nor eliminate the tank as a weapon system. Scoring the location of hits obviously would require multiple sensors, both increasing the costs and the burden on umpires.

In any case, the MILES approach will likely suffer from many of the same shortcomings as an evaluation device that REALTRAIN does. Absolute performance standards cannot be set so long as the two-sided approach is maintained. However, there is no question but what the approach will provide excellent training.

(f) Other approaches. Several other approaches to and devices for team training and evaluation have been developed. However, they either differ little in concept from those discussed, or, are of only marginal relevance to the development of tank crew MOE. For example, the Marine Corps is preparing to field a Tactical Warfare Analysis and Evaluation System (TWAES).⁵⁹ The approach is very similar to REALTRAIN, with some added hardware sophistication to improve control and provide near real-time casualty assessments. The US Air Force and US Navy have developed some highly sophisticated computerized simulations, but the missions assigned are so unlike those given tank crews that they did not appear to be relevant. Therefore, these approaches will not be discussed. The reader interested in brief descriptions of these approaches/devices should consult Wagner, et al.⁶⁰ or Larson, et al.⁶¹

(g) Summary. Current approaches to evaluating training effectiveness and operational readiness that are relevant to tank crews can

⁵⁹E. H. Rocklyn, et al. *A Method for Increasing the Training Effectiveness of Marine Corps Tactical Exercises: A Pilot Study*, NPRDC Technical Report 75-34, Navy Personnel Research and Development Center, May 1975.

⁶⁰Wagner, et al., *op. cit.*

⁶¹Larson, Sander, and Steinemann, *op. cit.*

be divided into those concerned exclusively with gunnery, and those concerned with tactical training in two-sided engagements. Those concerned with gunnery are attempting to develop reliable and valid measures of this extremely important aspect of performance. Performance standards are being derived so that it will be possible to determine whether a given crew performs at the minimally acceptable level for each of several types of gunnery. Also, it will be possible to compare the performances of two different crews, or to compare the performances of the same crew on different occasions.

The two-sided, free-play tactical engagement approaches appear to be much better suited to training than evaluation. Whatever is learned about warfare from experience can probably be learned from these exercises. Soldiers can practice their individual and team skills in a realistic context, where cues to action are taken from the situation rather than from a test monitor. The competitive situation and the desire to "survive" are undoubtedly motivating.

Commanders can undoubtedly evaluate gross aspects of performance in two-sided exercises by carefully observing the action and conducting thorough after-action debriefing sessions. However, these approaches do not, in the opinion of the authors, provide the accurate measurement of proficiency necessary to reliably categorize teams as combat ready or not combat ready.

Research Needs

The research program outlined in this section is felt to be the minimum necessary if tank crew training effectiveness and operational

readiness are to be adequately evaluated. The order of listing of the projects indicates the authors' choice of priorities.

I. Determine the reliability of the current Table VIII. It is realized that Table VIII will very probably be modified at some time in the future. However, it is currently being used by commanders to evaluate their crews, and decisions which affect careers are being made on the results. Annual firings also consume considerable resources. Commanders and crews both have a need and a right to know whether scores obtained are reliable indicators of performance, or whether chance factors play the primary role. In fact, if the reliability of the current Table VIII proves to be unacceptable, its use should be greatly curtailed, and the resources saved applied to a "crash" program aimed at improving its reliability.

As a minimal test of the reliability of Table VIII, the following procedures are proposed:

(a) One TOE battalion should be designated for the test, stabilized, and dedicated for a minimum of 120 days. Crew assignments should be finalized for a minimum of 60 days prior to any testing, and remain intact throughout the testing. If, for emergency reasons, a crew cannot be kept intact for at least 30 days prior to firing Table VIII, it should be dropped from the study.

(b) All crews should follow the normal training routine and fire Tables I through VII before firing Table VIII.

(c) Independent observers/evaluators from another unit should serve during the firing of Table VIII. Crews who have completed firing should be segregated from those who have not to prevent any "G-2" con-

cerning the test. Meticulous records of all events should be kept so that each run can be reconstructed after the fact. Scores should be derived employing the observers' hit determinations. However, close-in TV monitors should be placed near every target, if possible, so that an independent determination of hits could be made from the tapes.⁶²

(d) The intact crews should be transported, along with their own tanks, to another Table VIII location, and retested. The same procedures described in (c) above should be followed.

(e) The statistical reliability of the total score and the scores for selected engagements should be determined. The analysis of scores for separate engagements should provide information on which kinds of engagements contribute most to unreliability. More will be said concerning this in the second proposed research effort. Also, other analyses should be conducted as deemed appropriate after the data are examined. For example, some crews may tend toward the use of precision engagements, while others tend toward the use of the battlesight. The effects of such preferences on reliability should be studied.

If video equipment can be employed, the validity of the observers' hit determinations can be assessed. Also, total scores can be recomputed on the basis of the hits observed on the video tapes. If the validity of the observers' determinations is low, these scores based on video tape observation should prove to be much more valid than those obtained in the normal manner. If so, it might be possible for the armor community to justify the one-time costs associated with the use of

⁶² Video equipment is currently being employed for this purpose at Fort Hood, Texas.

additional video equipment, and the equipment could be used routinely to improve Table VIII scoring.

The major problem associated with this type of work (in addition to the resource requirements) is the subjectivity involved with the interpretation of the results. Personnel familiar with this kind of testing would probably agree that a total score reliability coefficient of 0.70 or higher was acceptable. Similarly, they would probably agree that a reliability of 0.30 or less was unacceptable. However, there would probably be considerable disagreement about where an exact line should be drawn. Therefore, regardless of the outcome, it is proposed that a description of the test and an interpretation of the results be published and circulated widely through the armor community. The discussion on reliability and the meaning of the numbers obtained should be in layman's terms for the benefit of those with little background in test theory and statistics. Individual commanders will then be better able to understand the problems associated with interpreting scores, and can decide for themselves how much faith they wish to put in the results of Table VIII scores.

II. Determine the number of replications required for each type of engagement. In order to ensure the reliability of any future Table VIII, the items entering into the total score must also have a reasonable reliability. The data obtained in Study I should provide some indications concerning the reliability of the items, i.e., of the various kinds of engagements. Whether the less reliable items can be made reliable by increasing the number of replications is not known. If they cannot, they should be eliminated from the exercise altogether. If

they can be made acceptably reliable with a feasible number of replications, the replications should be built into the Table VIII exercise. However, scoring would have to be adjusted to ensure that those engagement situations requiring the most replications were not given undue weight in the total score.

In order to determine the number of replications required, the following research study is proposed:

(a) The two engagement types believed to be the least reliable based on data from the first study should be selected. One engagement type believed to be moderately reliable and one engagement type believed to have good reliability should also be selected.

(b) A representative platoon (five tanks) from a TOE unit should be designated for the test, stabilized, and dedicated for a minimum of 180 days. Crew assignments should be finalized for a minimum of 60 days prior to any testing, and remain intact throughout the testing.

(c) All crews should fire Tables I through VII as part of their normal training routine during the first 60 days.

(d) All crews should fire those four types of engagements selected from Table VIII a minimum of 10 times each in as short a period of time as is feasible. Scoring should be accomplished in the same manner as in Study I.

(e) The reliability of each engagement type should be estimated employing the odd/even split technique.

(f) If the results indicate that the reliability of the scores for the different types of engagements can be sufficiently im-

proved⁶³ by a feasible number of replications, the reliability of other engagements of questionable reliability should be investigated in another study.

The original estimates which led to the selection of the elements to be studied may prove to be incorrect. That is, the two with suspected low reliability might prove to be sufficiently reliable, while the two expected to have higher reliabilities may not. In such a case, it would be wise to conduct a similar study with all the remaining elements in the Table, and with any new engagements proposed for a new Table VIII.

III. Develop MOE for functions other than gunnery. Gunnery is certainly a necessary and extremely important function of a tank crew but is far from being the only function required for effectiveness. As Prall⁶⁴ has succinctly stated the tanker's mission, the crew must be able to MAINTAIN, MOVE, SHOOT, COMMUNICATE, SEE, and SURVIVE. No standard MOE for any of these functions other than SHOOT apparently exist for tank crews. Individual testing at the crew level or higher, if conducted at all, is based on measures developed at the unit level. In order to ensure maximum total effectiveness, MOE for these other functions must be developed. A research program to develop these MOE is outlined below:

⁶³What level of reliability will be considered acceptable will have to be determined by consensus in advance. These could be referenced to the probability of misclassification as proficient or nonproficient (see Steinheiser and Snyder, footnote 39).

⁶⁴E. L. Prall. "Tank Crew Proficiency Testing," *Armor*, September-October 1975, 13-16.

(a) Determine the critical tasks for each function. Each of the functional areas will be composed of a number of tasks and subtasks. For example, as tasks under SURVIVE, Prall⁶⁵ lists "ATGM counterdrills, selection of positions, selection of routes, camouflage, establishing local security, mine warfare, extinguishing tank fires, and preparing the tank for a friendly nuclear strike." Some might disagree with this selection, others might wish to categorize the major functions differently or use different titles. However, how the functions are categorized is unimportant so long as the list is exhaustive. Therefore, the procedures to be followed are:

(1) Develop a list of categories for the major tank crew functions.

(2) Develop a list of tasks within each function category. As comprehensiveness is important, FMs, TMs, research reports, relevant periodicals, other military publications, and experienced armor personnel should all be consulted. Task statements at this point should be somewhat general in nature, e.g., "conduct preoperational checks."

(3) Develop brief definitions for each task statement to ensure a common understanding.

(4) Employ the Delphi Technique⁶⁶ with a group of experienced armor personnel to develop a consensus on the criticality of

⁶⁵Ibid.

⁶⁶The Delphi method is an iterative technique designed to obtain a consensus in terms of numerical ratings, usually from experts in a field. (For a description of the process by the developers, see N. C. Dalkey and O. Helmer, "An Experimental Application of the Delphi Method to the Use of Experts," *Management Science*, April 1963, 9(3), 458-567.) The method has been shown to be more accurate than the resultant opinion from group discussion, in at least one instance. (See N. C. Dalkey, *The Delphi Method: An Experimental Study of Group Opinion*, Memorandum RM-5888-TR, The Rand Corporation, June 1969.)

each of the tasks. The iterations should be designed to obtain information on which tasks must be evaluated to give a commander confidence in the combat readiness of his crews. Respondents should also be allowed to suggest additional tasks on the first round.

The final product of this phase of the work will be a list of tasks which consensus indicates are sufficiently critical that they must be evaluated in order to certify a crew as fully qualified.

(b) Determine which tasks are team tasks. Many of the tasks which are judged to be critical may not be true team tasks. That is, they may be simply an aggregation of individual tasks where there is no interdependence, interrelationship, or needed cooperation between crew members. Performance on such tasks does not need to be measured in a crew context. Team testing should be reserved largely for those tasks which do require cooperative and interrelated effort.

The procedures proposed for this part of the work are:

(1) Develop definitions of team and individual tasks, and illustrate with examples from outside the field of armor.

(2) Submit the definitions and the lists of critical tasks to a group of armor experts. The group, as individuals, should classify each task as being either a crew task or an aggregate of individual tasks. The group members should be required to provide justification for classifying a task as a crew task.

(3) On the basis of the group's opinions, classify each task as either a crew task or an aggregate of individual tasks. Where substantial agreement is lacking and the tasks cannot be easily classified, a panel should be formed to further examine the tasks. The panel

should be composed of members with differing opinions. If agreement on the classification cannot be reached on any task, the task should be at least temporarily classified as a crew task to ensure that no crew functions are deleted.

The product of this phase of the effort should be a list of tasks which are both critical and truly team tasks.

(c) Develop subtask and activity lists for team tasks. This phase is designed to determine exactly what a crew must do to accomplish a task. It is proposed that a method developed by Suchman, et al.,⁶⁷ be employed. The procedures involved are outlined briefly below:

(1) Convene a panel of five or more knowledgeable individuals in the field. The composition of the panel does not need to remain fixed, as any expert in the field can be "read in" to what is going on in a very short time. The first job of the panel is to develop a complete listing of subtasks for each task. The names given subtasks do not have to be behavioral. For example, under a possible task concerned with preventative maintenance, a subtask might be "inspects tracks for defects and wear."⁶⁸

(2) Develop a list of "activities" for each subtask. The activity statements should be specific and behavioral. For example, in inspecting a track for defects or wear, exactly what the crewman inspects should be specified. Also, the standards he employs to determine whether the track is serviceable or requires repair should be

⁶⁷ J. R. Suchman, A. L. Kubala, and J. E. Taylor. *The Development of an Open-Access, Performance Oriented Curriculum for Training the Military Policeman (MOS 95R20)*, Final Report FR-WD(CA)-75-9, Human Resources Research Organization, Alexandria, Virginia, June 1975.

⁶⁸ This task title is given only as an example of the relative specificity required. It is not implied that this either is or is not a team task.

specified. The activities and standards provide all the information necessary for the development of a performance test or tests.

(3) Develop a series of exercises to evaluate performance on the critical crew tasks. Each exercise may include a whole series of tasks or only a few subtasks. However, they should be designed so that the cues available for initiation of the activities are the same as those that would be available in a combat situation. These exercises are the performance tests which incorporate the standards involved in (2). In other words, these exercises will be the MOE for the tasks involved.

The procedures outlined may seem to be very involved and time consuming. However, in practice they have proved to be quite efficient. Disagreements have been readily resolved, and the techniques have seemed to be equally applicable to both "soft" and "hard" skills.⁶⁹ Instructors have found it quite easy to develop a series of parallel forms of performance tests which accounted for various common alternative sequences of events, while still measuring all the critical aspects of performance.

Other procedures might be followed. For example, Larson and Sander⁷⁰ employed the Delphi method to determine exactly what aspects of combat performance battalion commanders would like to measure if they could. The approach might lead to a different set of MOE for tank crews, as it

⁶⁹Soft skills have also be defined as "man-ascendant," and hard skills as "machine-ascendant." Interviewing a witness or a suspect would be classified as a soft skill, while repairing a radio set would be classified as a hard skill.

⁷⁰O. A. Larson and S. I. Sander. *Development of Unit Performance Effectiveness Measures Using Delphi Procedure*, TR 76-12, Navy Personnel Research and Development Center, San Diego, California, September, 1975.

does not assume a set of specific tasks. However, the approach proposed seems preferable for this research area as the unit is specified as tank crews. Larson and Sander did not specify the unit, although they did request information on which MOE were applicable to what size units. Furthermore, the approach proposed results in a list of specific activities and standards, while the Delphi method did not. The chief advantage of the Larson and Sander approach is that it allows commanders to state what they want to measure without being restricted to a set of particular tasks. Therefore, if time and resources are available, the Larson and Sander technique should be used to ensure that the final MOE chosen are comprehensive, as the procedure might result in suggested tasks not uncovered by the proposed procedures.

Summary

The development of MOE for teams is not a simple task. Numerous problems confront the developer. He must try to ensure that his MOE are comprehensive, reliable, and economical. He must try to ensure that they measure critical tasks which are truly team tasks, rather than simply measure an aggregate of individual tasks. He must also decide on whether a particular set of combat skills can best be measured by one-sided or two-sided tests, and he must ensure that processes as well as outcomes are evaluated so that (process) information can be fed back to training managers.

Three research efforts are proposed as a first step in developing MOE for tank crews. The first two pertain to the all important function of gunnery, and are designed to ensure that MOE for gunnery are worth

the resources expended and of real value to commanders. The third represents an attempt to derive MOP for functions other than gunnery.

Early in this chapter, the authors concluded that the measurement of tank crew proficiency is a must. They further concluded that the question of "whether" we measure effectiveness is not as important as "how" we acquire the means to do so. Hopefully, if the proposed research outlined in this chapter is conducted, our means of qualifying tank crews will be greatly improved.

Chapter V

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